International Earth Rotation Service (IERS)
Service International de la Rotation Terrestre

IERS Annual Report 2001

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IERS Annual Report 2001

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1 Foreword

You are opening the IERS Annual Report for the year 2001, the first one worked out by the 'new' IERS after its recent reorganization. Its contents therefore reflects, quite naturally, all changes introduced under the new structure of the Service. The changes concern mainly Section 3 Reports of IERS components:

- There is a new part (Section 3.3) covering the activities of the Analysis Coordinator;
- The parts devoted to the Technique Centres (Section 3.4) are limited to enlarged abstracts only, because these activities are expected to be more widely discussed by these components (that are now independent International Services) themselves, in their own Annual Reports;
- Similar holds for the Product Centres (Section 3.5), some of which also intending to publish their full reports separately;
- The Combination Centres, both for the ITRS and those doing the research, are the new components whose reports can be found in Section 3.6.

It is necessary to mention that the new structure of the IERS and its products are not 'frozen' forever, they are subject to constant re-discussion to reflect both the progress of the research made within the major scientific communities interested in the Service (i.e., in astronomy, geodesy and geophysics) and the needs of the users. The main ground for these discussions are the IERS Workshops that are organized irregularly, whenever the need to hold them appears. Thus the flexibility and further evolution of the Service is assured for the future.

Jan Vondrák
(Chairman, IERS Directing Board)

2 The IERS
2.1 Structure

In 2001 and 2002, the IERS had the following components. For their functions see the Terms of Reference (Appendix 1), for addresses and electronic access see Appendices 3 and 4. If not indicated otherwise, the components were established on 1 January 2001. IGS/ILRS/IVS became Technique Centres on this day.

Analysis Coordinator

Markus Rothacher

Central Bureau

Director: Bernd Richter

Technique Centres

International GPS Service (IGS)
IGS Representatives to the IERS Directing Board:
Carine Bruyninx, Robert Weber
IERS Representative to the IGS Directing Board:
Claude Boucher

International Laser Ranging Service (ILRS)
ILRS Representatives to the IERS Directing Board:
Ron Noomen, Peter Shelus
IERS Representative to the ILRS Directing Board:
Bob E. Schutz

International VLBI Service (IVS)
IVS Representatives to the IERS Directing Board:
Chopo Ma, Axel Nothnagel
IERS Representative to the IVS Directing Board: Chopo Ma

International DORIS Service (IDS) - planned
DORIS representative to the IERS with observing status:
Pascal Willis

Product Centres

Earth Orientation Centre
Primary scientist and representative to the IERS Directing Board: Daniel Gambis

Rapid Service/Prediction Centre
Primary scientist and representative to the IERS Directing Board: Jim Ray (until May 2002)

Convention Centre
Primary scientists: Dennis D. McCarthy, Gérard Petit
Current representative to the IERS Directing Board:
Dennis D. McCarthy

ICRS Centre
Primary scientists: Ralph A. Gaume, Jean Souchay
Current representative to the IERS Directing Board: Jean Souchay

ITRS Centre
Primary scientist and representative to the IERS Directing Board: Claude Boucher

Global Geophysical Fluids Centre
Head and representative to the IERS Directing Board: Benjamin F. Chao

Special Bureau for the Atmosphere
Chair: David A. Salstein

Special Bureau for the Oceans
Chair: Richard S. Gross

Special Bureau for Tides
Chair: Richard D. Ray

Special Bureau for Hydrology
Chair: Clark R. Wilson

Special Bureau for the Mantle
Chair: Benjamin F. Chao

Special Bureau for the Core
Chair: Veronique Dehant (until June 2002), Tim van Hoolst (since July 2002)

Special Bureau for Gravity/Geocenter
Chair: Michael M. Watkins

Special Bureau for Loading (established on 1 February 2002)
Chair: Tonie van Dam, *Vice-chair*: Hans-Peter Plag

Combination Centres

ITRS Combination Centres

Deutsches Geodätisches Forschungsinstitut (DGFI)
Primary scientist: Hermann Drewes

Geomatics Canada, Geodetic Survey Division (since February 2002)
Primary scientist: Remi Ferland

Institut Géographique National (IGN)
Primary scientist: Zuheir Altamimi

Combination Research Centres

CRC representative to the IERS Directing Board:
Sheng Yuan Zhu

Astronomical Institute, Academy of Sciences of the Czech Republic, and Department of Geodesy, Czech Technical University, Prague
Primary scientist: Jan Vondrak

Deutsches Geodätisches Forschungsinstitut (DGFI)
Primary scientist: Detlef Angermann

Forschungseinrichtung Satellitengeodäsie, Technical University Munich (FESG)
Primary scientist: Markus Rothacher

Forsvarets forskningsinstitutt (FFI, Norwegian Defence Research Establishment)
Primary scientist: Per Helge Andersen

GeoForschungsZentrum Potsdam (GFZ)
Primary scientist: Sheng Yuan Zhu

Geodetic Institute of the University of Bonn (GIUB)
Primary scientist: Axel Nothnagel

Groupe de Recherches de Géodésie Spatiale (GRGS)
Primary scientist: Richard Biancale

Institute of Applied Astronomy, St. Petersburg (IAA)
Primary scientist: Zinovy Malkin

Institut Géographique National (IGN)
Primary scientist: Patrick Sillard

Jet Propulsion Laboratory (JPL)
Primary scientist: Richard S. Gross

2.2 Directing Board

In 2001 and 2002, the IERS Directing Board had the following members (for addresses see Appendix 2):

Chair	Jan Vondrák
Analysis Coordinator	Thomas Herring (until August 2001) Markus Rothacher (since September 2001)
Product Centres Representatives	
Earth Orientation Centre Representative	Daniel Gambis
Rapid Service/Prediction Centre Representative	Jim Ray (until May 2002)
Conventions Centre Representative	Dennis D. McCarthy
ICRS Centre Representative	Jean Souchay
ITRS Centre Representative	Claude Boucher
Global Geophysical Fluids Centre Representative	Benjamin F. Chao
Central Bureau Representative	Bernd Richter
Combination Research Centres Representative	Sheng Yuan Zhu
Technique Centers Representatives	
IGS Representatives	Carine Bruyninx Robert Weber
ILRS Representatives	Ron Noomen Peter Shelus
IVS Representatives	Chopo Ma Axel Nothnagel
IDS Representative (observing status)	Pascal Willis
Union Representatives	
IAU Representative	Jan Vondrák
IAG / IUGG Representative	Clark R. Wilson
FAGS Representative	David Pugh

3 Reports of IERS components
3.1 Directing Board

The IERS Directing Board (DB) met twice in the course of the year 2001. Short summaries of these meetings are given below.

Meeting No. 33 *Monday, March 26, 2001, Congress Centre, Nice, France*

J. Vondrak thanked C. Reigber for his activities as representative of IAG and as chair of the IERS directing board in the years 1995 to 2000 and presented to him a "Certificate of Appreciation for Outstanding Service".

Reports on major activities since the last meeting and on the work of the IERS components were presented. The Central Bureau (CB) was asked to organise a full day meeting right before or after the IAG meeting in Budapest as a come-together meeting for all IERS Combination Research Centres. The CB was also asked to initiate a survey within the IERS to specify the various requirements of the PCs, ITRF CCs and CRCs from the various techniques.

The following decisions were made: There will be no IERS workshop organized in 2001 but in 2002 right before or after the EGS meeting. The old style (activity reports and results) will be kept more or less also for the IERS Annual Report 2000.

D. McCarthy announced the establishment of an UTC working group to translate the IAU recommendations.

Meeting No. 34 *Wednesday, September 26, 2001, Royal Observatory of Belgium, Brussels, Belgium*

J. Vondrak welcomed especially C. Ma as the only American participant at this meeting and expressed his sympathy for the American folk after the shocking terrorism attack. C. Ma wished to see his participation as a sign that normal work will go on. Due to the horrible events in the USA of September 11 and the ensuing problems for the American Board members to participate in this meeting, all decisions were postponed for later e-mail approval.

M. Rothacher was welcomed as the new IERS Analysis Coordinator.

Reports on major activities since the last meeting and on the work of the IERS components were presented. It was discussed whether EOP quantities should be given in equivalent units either arcseconds and seconds or in mas and ms. Several board members expressed their concerns about a change in the EOP format; a small group of specialists should discuss this in detail. C. Boucher proposed an ITRF Advisory Group. The goal of this group would be to advise the ITRS Centre about ITRF product selection and quality. Objectives are to evaluate ITRF2000 and to define the organization for future ITRF computation using several Combination Centres. On behalf of B. Chao, C. Ma presented a proposal by B. Chao and Hans-Peter Plag on "Establishing the Special Bureau for Loading, in the Global Geophysical Fluids Center (GGFC)". A proposal by J. Ray on an IERS Analysis Campaign to align EOPs to ICRF / ITRF2000 was explained by M. Rothacher.

As a result of the CRC meeting in Budapest, the IERS Workshop should be also devoted to combination problems (besides a discussion of the implementation of the IAU Resolutions to the ICRS). As location there are 2 proposals: Paris Observatory and Munich.

The Central Bureau was asked to compile a list of all meeting dates which are of relevance to the IERS, including workshops of Technique Centres. B. Richter proposed to publish a summary of the DB meeting minutes in the Web to make the decisions and recommendations of the board more visible for the public.

Votes collected by e-mail after the meeting:
Establishing a new GGFC Special Bureau: accepted
Setting up an ITRF Advisory Group: accepted
Place of next IERS Workshop 2002: Paris
Summaries of DB meeting minutes to be published in the IERS Web pages: accepted
Next IERS directing Board meeting: in connection with the IERS Workshop

3.2 Central Bureau

The Central Bureau (CB) at Bundesamt für Kartographie and Geodäsie (BKG) in Frankfurt am Main began its work. The transition of the duties from the former CB at Observatoire de Paris was mainly finished at the end of 2000, and on 1 January 2001 the new CB started officially.

One of the first tasks was the establishment of the web site <www.iers.org>, which went online on 1 January 2001. Texts from the former IERS web site at Paris were used, reformatted and partially updated. A number of new documents were created. The web pages give information on the structure of the IERS, its products and publications and provides contact addresses as well as general facts on Earth rotation studies. Also a large link list for IERS, Earth rotation in general and related fields was added. Throughout 2001 the web site was regularly enlarged and updated.

The CB organized and documented two IERS Directing Board (DB) meetings: No. 33, March 26, 2001, Congress Centre, Nice, France; No. 34, September 26, 2001, Royal Observatory of Belgium, Brussels, Belgium. Between these meetings the CB coordinated the work of the DB.

The CB presented the new structure and the activities of IERS at the EGS 2001 in Nice and at the IAG 2001 Scientific Assembly in Budapest. There also a first meeting of the Combination Research Centres was organized on September 7, 2001.

During the year 2001, 20 IERS Messages were edited and distributed by the CB. These replaced the former IERS Gazettes and serve for short or urgent information for the IERS users. They contain news from the IERS and from related services as well as announcements of conferences.

The CB edited and published an online version of the IERS Annual Report 2000. Besides the reports of the IERS components, it contains information on the IERS compiled by the CB.

From the former CB and the Rapid Service/Prediction Centre the CB received four mailing lists with regular and electronic addresses of about 2500 IERS users. These lists were merged and formed the basis for an IERS address database. Several inconsistencies between the different mailing lists, outdated addresses and users with different addresses could be identified. During the year, a considerable number of new users were added. Address and subscription information has regularly been updated.

To support the IERS data base project a proposal was launched in the framework of the "Geotechnologien-Programm" initiated by the German Ministry of Education and Sciences. After successful reviews a scientific position has been granted for 3 years.

Bernd Richter, Wolfgang R. Dick

3.3 Analysis Coordinator

Introduction

Although the new structure of the IERS was already implemented on January 1, 2001, the work of the current IERS Analysis Coordinator officially started only at the IERS Directing Board Meeting in September 2001 in Brussels. This report will cover the activities from September to December of 2001.

Goals and Time Schedule of the IERS Analysis Coordination

The major goals of the IERS Analysis Coordination, as presented in Brussels in September 2001, may be grouped into five major tasks as follows (see also Figure 1 below):

(1) Coordination of CRC activities: an ongoing process.

(2) Status / list of present IERS products and their methods of generation

a) Compile a complete list of present IERS products containing the following information:

- When generated? How often? With what delay?
- Availability, where?
- Accuracy, consistency
- Detailed description of algorithms used (combination methods, weighting, standards, …), references to publications, web pages
- Details on how the products should be used?

b) Status of global station network

- Compile the status of the global network together with the CSTG Subcommission on the ISGN and the ITRF Product and Analysis Centres
- Assess status of local ties, site logs, etc.
- How global is the site distribution?

c) Use of IERS standards

- Compile a complete list of the standards used by the various techniques and by individual ACs

d) Documentation

- Check for the availability of IERS product descriptions
- Are product generation methods documented?
- Are format descriptions available?
- Are product changes tracked?

(3) Plan for the optimisation of the consistency and accuracy of the products. A plan has to be development with the different IERS components on how to achieve this goal.

a) Global station network
- Strive for a global distribution of collocated sites
- Encourage GPS receiver implementation at every site occupied by SLR or VLBI
- Improve local ties

b) Optimisation of the products of individual techniques
- Responsibility of the Technique Analysis Coordinators
- Combination of techniques –> systematic errors, quality information –> feedback to technique centres –> improvements

c) Standards concerning modelling, processing and parameterisation
- Make sure that IERS standards are used
- Establish three types of standards: modelling, processing and parameterisation standards
- Standards have to be continuously improved (IERS Convention Centre, IERS Analysis Coordinator, Technique Centre Analysis Coordinators). With what methods?

d) Combination strategies and methods
- Final goal: rigorous combination of ITRF/ EOP/ ICRF, including all common parameters
- A task of the CRCs (software development, …)

(4) Implementation of new combination strategies. A procedure in two steps is proposed:

(A) “Weekly” solutions

1. Generation of “weekly” solutions in SINEX by Analysis Centres of individual tech-niques with station coordinates + EOP (+ ICRF)
2. Combination of “weekly” solutions of individual techniques by the Technique Services
3. CRC test and combine “weekly” technique solutions
4. Combined weekly solutions as the basis for final routine EOP products

(B) “Multiyear” solutions

1. Combination of “weekly” solutions into “multiyear” solutions including ITRF/ EOP/ ICRF.
2. Resulting ITRF + ICRF are used to produce fully consistent EOP series.

(5) Routine quality control of all IERS products

All the major information on the goals, the plans, the present status of the IERS analysis coordination work is available and maintained on the web pages of the IERS Analysis Coordinator. They give a good overview of the corresponding activities. Please have a look at the web pages to get an up-to-date impression of the present status of work.

In order to make progress towards the goals mentioned above the following primary activities were initiated in 2001:

- Compilation of a complete list of IERS products. The present status of the list has been implemented in the IERS web pages (see <http://www.iers.org/iers/products/>).
- IERS Campaign to align EOPs to ITRF2000/ICRF
- IERS SINEX format unification
- IERS SINEX Combination Campaign

The last three items are the topic of the next section, where the web pages are presented.

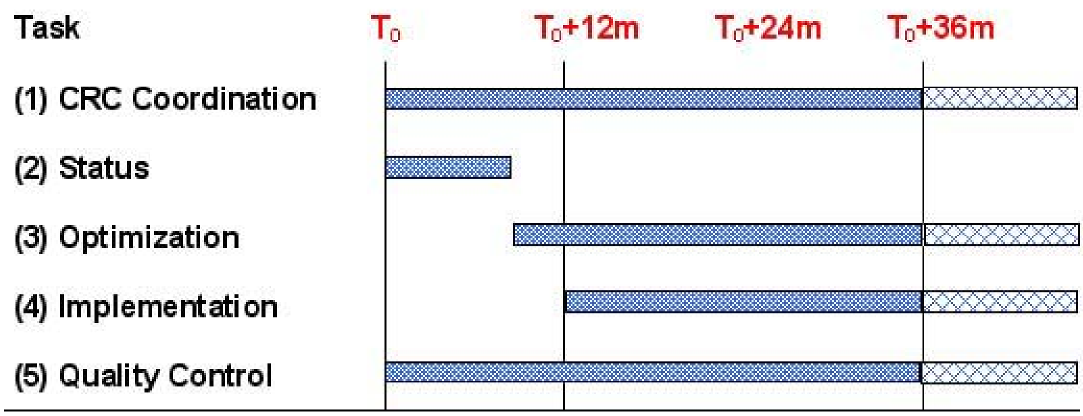
Web Pages

According to the proposed procedure, presented at the IERS Directing Board Meeting No. 34 in September 2001 in Brussels, a new web site was planned and installed in November 2001. This site should provide a communication and data exchange platform to the Combination Research Community. It should also stimulate and support their activities. The web site

<http://alpha.fesg.tu-muenchen.de/iers/>

presents the current activities and research intentions of the Combination Research Centres (CRCs), provides a communication platform with mail forum and e-mail exploder and builds the main

Figure 1. Time schedule of the IERS Analysis Coordination activities. T_0 = September 2001.



coordination of the IERS SINEX Campaign and the IERS Analysis Campaign to align EOPs to ITRF2000/ICRF. A more detailed description of the objectives and the planned activities can be downloaded from

<http://alpha.fesg.tu-muenchen.de/iers/annexIII.html>.

Communication

The IERS Central Bureau has installed a platform for a CRC discussion group in order to support e-mail discussions and the scientific transfer between the CRCs and interested persons. The e-mail support is subdivided into the e-mail exploder with restricted access and an e-mail forum, which is public to all interested persons. Anyone, who is interested in CRC concerning activities and wants to participate in the discussions can address himself to the IERS Central Bureau (A. Lothhammer, <lothhammer@iers.org>).

CRC Activities

The link
<http://alpha.fesg.tu-muenchen.de/iers/crc/crc%20activities.html>
is leading to CRC project list. This list should present an overview as up-to-date as possible of the current CRC activities. In addition to the institutions, names and contacts it includes their objectives, combination and research strategies, their future plans and links to further publications.

EOP Alignment Campaign

In September 2001 the IERS Analysis Coordinator presented the 'IERS Analysis Coordination Campaign to align EOPs to ITRF2000/ICRF' as originally proposed by Jim Ray. The intention of the IERS Alignment Campaign is to create EOP series with highest possible consistency with ICRF and ITRF2000. The aim of this project is to achieve an overall accuracy of 0.1 mas. This will lead to an intermediate solution until a rigorous combination of the EOP together with ITRF / ICRF is possible. Therefore it is necessary to analyse and understand the origin of systematic errors belonging to the reference frames. The IERS Alignment Campaign was started at the end of September 2001 with an initial call for participation. The campaign is subdivided into two parts. In a first step the Technical Centres were asked to produce EOP series with a reference frame fixed to the ITRF2000 / ICRF at the level of uncertainty. In addition, they were asked to produce solutions with different constraints on ITRF2000 (ICRF). The second step consists of the analysis of the submitted EOP series by comparison with the official annual solutions 2000 and by studying the consistency between the various series. The final results should be recommendations for future realizations of reference frames. The ongoing project can be accessed under

<http://alpha.fesg.tu-muenchen.de/iers/eop/campaign.html>.

The sublinks 'Call for Participation', 'Proposals', Submission of

EOP series', 'List of available EOP series' and 'Results' show the whole history and the processing of the Alignment Campaign.

SINEX Format

The web pages and the communication platform was used to develop a new SINEX format. The objective was to create a single, shareable and uniform SINEX format. This is a very basic requirement for the combination of SINEX files from all different Technique Centres. The most common SINEX format descriptions were analysed and a new uniform consistent version was proposed. The discussion about the new format (Version 2.00) was not finished until the end of the year 2001. Now the final version of the SINEX 2.00 format is available under
<http://alpha.fesg.tu-muenchen.de/iers/sinex/sinex_v2.pdf>
(see as well IERS Message No. 26).

IERS SINEX Combination Campaign

It is the intention of this campaign to combine „weekly“ solutions from SINEX files of different techniques with station coordinates and EOPs (and ICRF) and to assess systematic biases between the individual space geodetic techniques. The web pages were prepared and the Campaign was initiated at the beginning of the year 2002. Now the goals, the procedure and the participants can be found under
<http://alpha.fesg.tu-muenchen.de/iers/sinex/sinex_campaign.html>.

SINEX Data Pool

Parallel to the SINEX Combination Campaign a SINEX data pool is under construction. Various SINEX data are collected and archived to provide the CRC community with an easy to use data base for their research. An up-to-date list and links to a selected subset of SINEX files, suitable for combination research and software testing, is available in the SINEX file archive,
<http://alpha.fesg.tu-muenchen.de/iers/sinex/datapool.html>.

The web pages and connecting activities are supported by the scientific associates Dr. R. Dill and D. Thaller at the Technical University in Munich. We acknowledge the German Geotechnologien-Projekt of the BMBF for the funding of these activities.

Markus Rothacher, Robert Dill, Daniela Thaller

3.4 Technique Centres

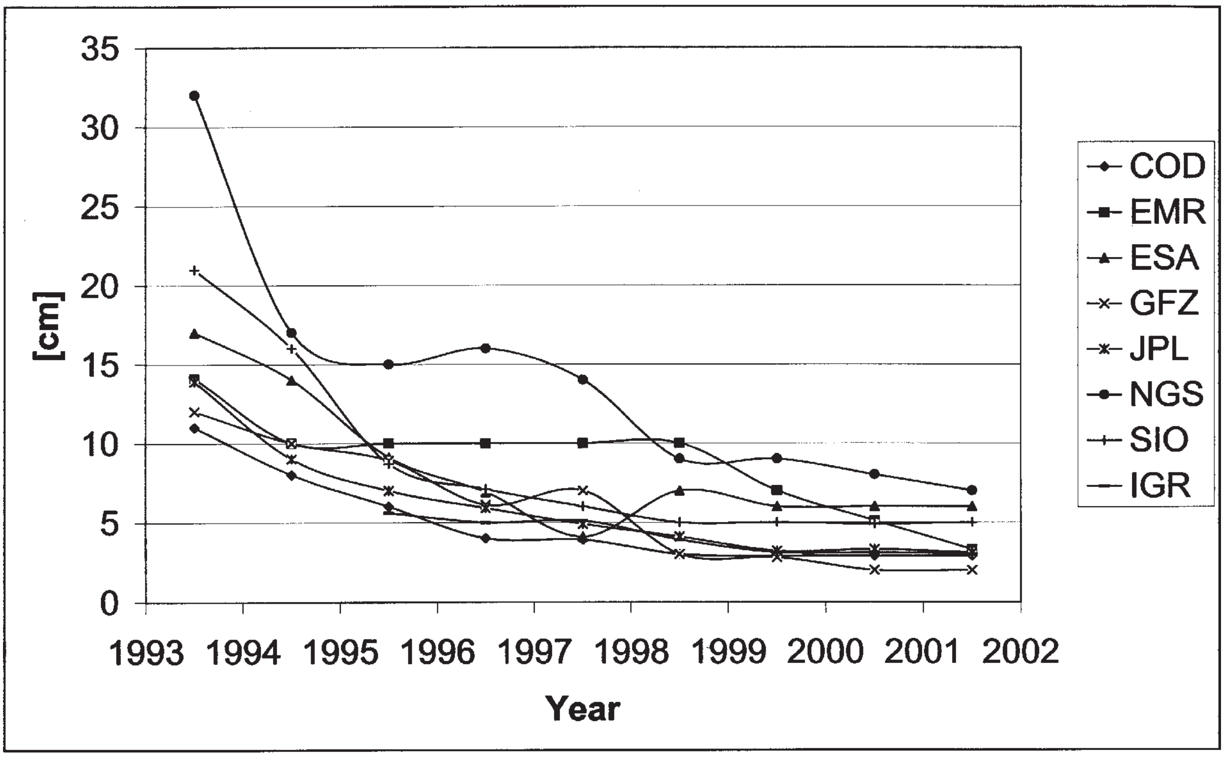
3.4.1 International GPS Service (IGS)

General The International GPS Service is committed to provide the highest quality data and products as the standard for global navigation satellite systems (GNSS) in support of Earth science research, multidisciplinary applications, and education. In this context the IGS offers a large number of consistent products which constitute the practical realization of the International Reference System and allow for an easy access to the most recent ITRF. Table 1 gives an brief overview of the estimated quality of these data sets at the begin of the year 2002.

Table 1: Quality of the IGS Reference Frame products as of January 2002 (for details see <http://igscb.jpl.nasa.gov/components/prods.html>)

Products Delay	Ultra-Rapid Real Time	Rapid 17 hours	Final 13 days	Units
Orbit	25.0	5.0	< 5.0	cm
Clock	5.0	0.2	0.1	ns
Polar Motion		0.2	0.1	mas
LOD		30.0	20.0	μs/d
Stations h/v			3.0/6.0	mm
Troposphere			4.0	mm ZPD

Figure 1: Weighted orbit RMS (WRMS) of the Analysis Center and the IGS Rapid (IGR) orbit solutions with respect to the IGS final orbits; WRMS values were smoothed for graphical representation



All products are based on a combination process of the individual IGS Analysis Centre (AC) solutions to ensure enhanced reliability. Figure 1 demonstrates the improvement in consistency of the AC's orbit solutions with respect to the combined IGS final orbit since 1994. End of 2001 several Analysis Centre solutions as well as the IGS rapid orbit were close to reach the 2 centimetre orbit precision level, also indicated by the IGS 7-day arc orbit analysis.

Tracking Network

In 2001 the IGS Central Bureau has added downloadable maps, demonstrating the distribution of the network stations, in several formats to the IGS server (<http://igscb.jpl.nasa.gov/>). In addition, a collaborative design of a future site log format, accommodating the planned inclusion of IGLOS stations, was completed. This new site log will be introduced in 2002.

Figure 2: IGS Global Station Network

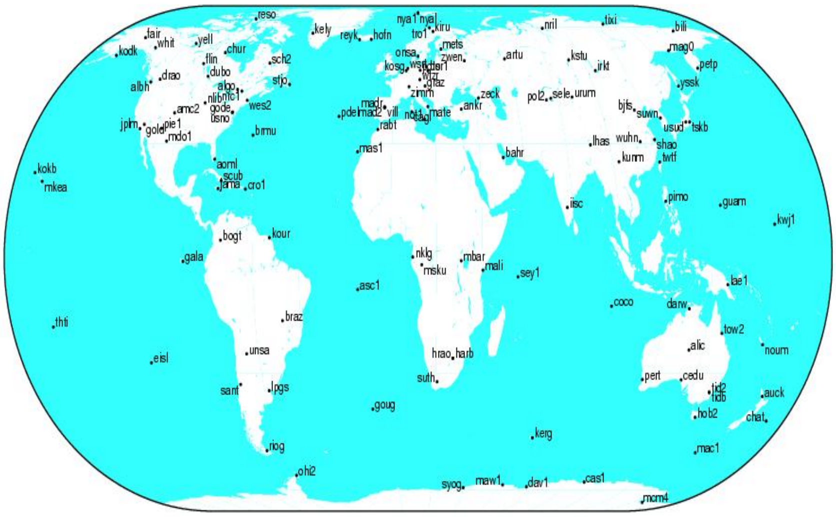


Figure 2 shows the so-called 'Global IGS stations network' which consists of about 110 sites as of begin 2002. Besides, there is a quite large number of additional IGS tracking stations, predominately located in the European, in the Central North American, and in the Southern Californian Region.

For further information see <http://igscb.jpl.nasa.gov/network/netindex.html>.

Africa

In order to encourage the installation of supplementary IGS tracking stations on the African continent (about ten stations at the end of 2001), IGS representatives participated to several meetings with representatives of African National Mapping Agencies.

Reference Frame

Since December 2001 (GPS-Week 1143) all IGS products are based consistently on the IGS Reference Frame realization (IGS00) of the ITRF2000. To perform this task the unconstrained weekly combined IGS-SINEX solution of station coordinates/velocities and ERP's is aligned by minimum datum constraints to IGS00, based on a list of 54 reference stations with high quality positions/velocities in ITRF2000. Previous to the combination also the individual orbit solutions are rotated by means of a spatial similarity transformation to this common frame.

IGS Projects

Within IGS a number of Working Groups focus on selected topics related to the IGS components. Furthermore Pilot Projects have been launched to develop new products and services. A few of them are briefly presented below. For a complete list and descriptions see <http://igscb.jpl.nasa.gov/projects/projindex.html>.

TIGA Pilot Project

In March 2001, the IGS set up the TIGA Pilot Project for monitoring tide gauge benchmarks for long-term sea-level studies. Within TIGA, data analysis will be performed with a very low latency, but with as much as possible stations included.

IGLOS Pilot Project

The International GLONASS Service - Pilot Project (IGLOS-PP) is a pilot service of the International GPS Service (IGS) to track and analyze data from the Russian GLONASS satellite constellation. The products from the Service should facilitate the use of combined GLONASS and GPS observations for scientific and engineering applications, and allow users to experiment with the combined systems as a prototype Global Navigation Satellite System.

The IGLOS - Pilot Project was expected to start in 2001, but was postponed until 2002. While from the analysis point of view, the GLONASS data could be perfectly integrated in the routine IGS operations unreliable station meta-data and the correct handling of the combined data within the data centres caused the major delays.

IGS/BIPM Pilot Project

The central goal of this pilot project is to investigate and develop operational strategies to exploit GPS measurements for improved availability of accurate time and frequency comparisons worldwide. This will become especially significant for maintaining the international Coordinated Universal Time (UTC) timescale as a new generation of frequency standards emerges.

LEO Meeting

Beginning of March, an IGS LEO Pilot Project Meeting was held in Potsdam, Germany. The primary purpose of this meeting was devoted to understanding upcoming Low Earth Orbit (LEO) missions carrying GPS flight receivers, with particular emphasis on CHAMP, in order to develop the goals, objectives and structure for the IGS LEO Pilot.

Outlook

In order to support real-time applications the IGS provides combined 'ultra-rapid' satellite orbits (IGU) in standard SP3 format since November 2000. Because this format is not flexible enough e.g. to characterize sufficiently the variable accuracy of the given data points within the IGU-orbits, a new format, preliminary labelled SP3c, has been developed. Furthermore the update cycle of ultra rapid products will go down from 12 hours to 3 hours. Both innovations will become effective end of 2002.

With the tremendous growth of the IGS and an increase in demanding applications, the IGS Board decided to develop a strategic plan for the IGS for the coming years. This strategic plan was finalised in 2001 and is available on request from the IGS CB (igscb@jpl.nasa.gov). Three key strategies have been identified to achieve the long-term goals and objectives of the IGS which are firstly *to ensure delivery of world standard GNSS data and products, providing the standards and specifications globally,* secondly, *to pursue new opportunities for growth to improve the services and serve a broader range of users* and finally *to continuously improve the effectiveness of the IGS organization*. The report, which further highlights the roles of the various IGS components, is thought to characterize the anticipated path of development of the Service over the upcoming 6 years.

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2002-2007 IGS Strategic Plan
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2000 IGS Technical Reports
IGS Central Bureau, eds.
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2000 IGS Annual Report
IGS Central Bureau, eds.
Pasadena, CA: Jet Propulsion Laboratory, 2002.

These documents are also available via FTP at
<ftp://igscb.jpl.nasa.gov/igscb/resource/pubs/>.

Network, Data and Analysis Center Workshop 2002
Workshop Recommendations
<http://www2.geod.nrcan.gc.ca/~pierre/
workshop_reco_website.htm>

Network, Data and Analysis Center Workshop 2002
Summary of 2002 IGS Workshop
[IGSMAIL-3845]:
<http://igscb.jpl.nasa.gov/mail/igsmail/2002/msg00183.html>

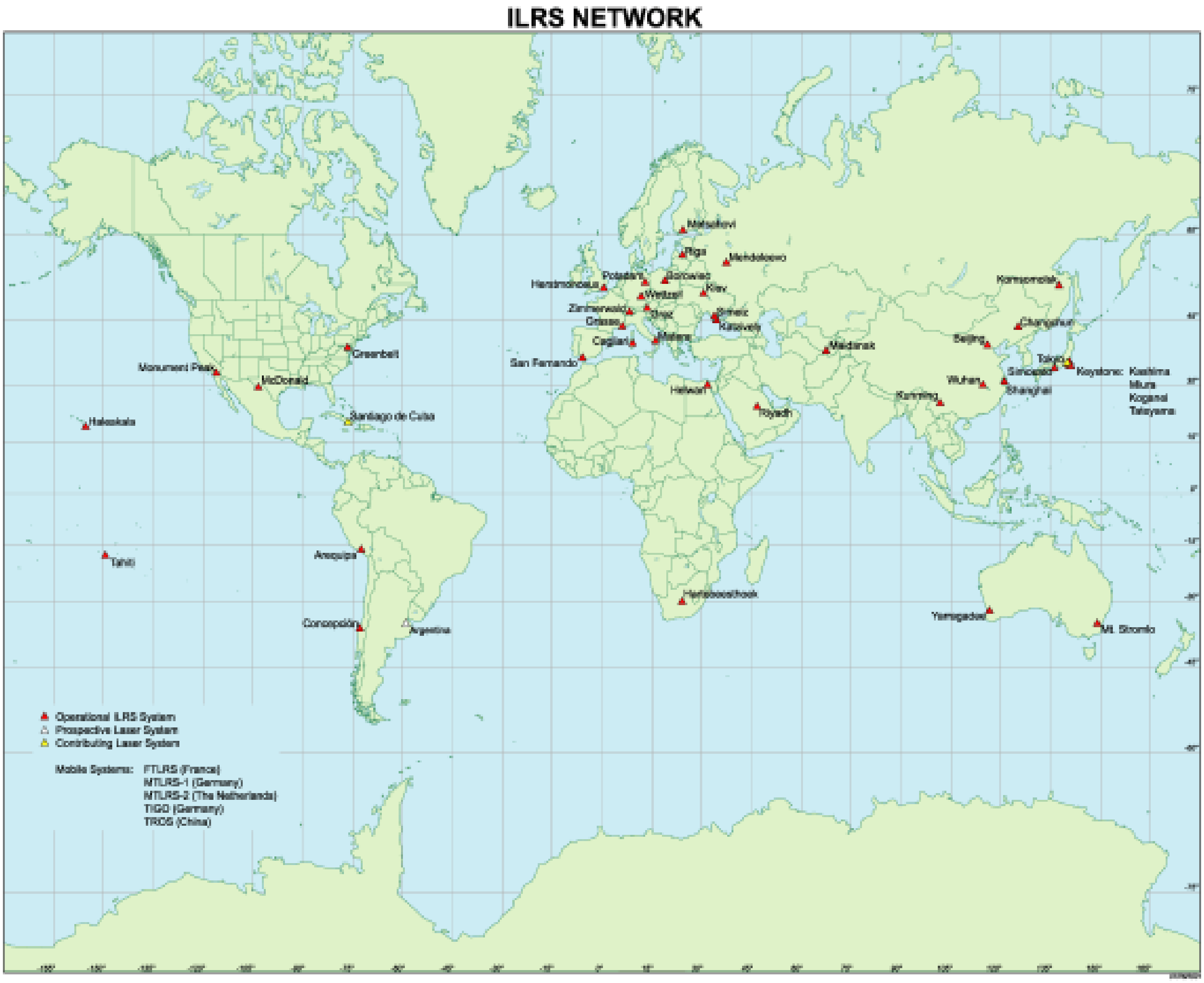
Robert Weber, Carine Bruyninx

3.4.2 International Laser Ranging Service (ILRS)

Introduction

The International Laser Ranging Service (ILRS), established in 1998, is responsible for the coordination of SLR/LLR missions, technique development, operations, analysis and scientific interpretation. Within the organizational structure of the IERS, the ILRS is one of several Technique Centers, having accompanying responsibilities for the generation and quality assurance of Earth Orientation and related products that are generated within the laser technique. An overview of the network of SLR/LLR stations (status June 2002) is given in Figure 1. Traditionally, the Southern Hemisphere coverage of the network is poor, but it must be noted that the geometric strength has improved recently with the installation of new observing systems in Concepcion (Chile) and Hartebeesthoek (South Africa). The maturity of the ILRS, now into its fourth year, is also reflected in the development of its organization and projects.

Figure 1: The network of ILRS tracking stations (status June 2002; source: ILRS homepage).



Activities in 2001

Although the satellites and stations are indispensable for the ILRS contribution to IERS, this overview will concentrate on analysis activities. Within the ILRS, the Analysis Working Group (AWG) is responsible for the coordination of these activities, including the development of quality control procedures as well as official ILRS analysis products. Two AWG workshops were held in 2001, notably in Nice (March) and in Toulouse (September). Within these workshops, analysis and data product issues are discussed, projects and/or campaigns are initiated and evaluated. As an example, the use of the SINEX format for the exchange of scientific results among the various observational techniques, was mandated for use within the ILRS. This use, internal to the ILRS, led to comments, advisories and suggested modifications. This provided important contributions to the development of the generalized SINEX V2.0 format.

With the development of (an) official ILRS product(s) and the quality control (QC) issue (of observations and products) in mind, the AWG has initiated a number of pilot projects. They are clearly developing with time. One pilot project concerns the harmonization of semi real-time QC results, the quality assessment of the SLR observations in particular. One of the most important conclusions from this project is that the model for station coordinates plays a major role in the diversity of quality „verdicts“ that are generated and distributed to the stations each week. Since the ITRF2000 solution has become fully available during this reporting year, and this model is known to be a state-of-the-art representation of actual station positions, the AWG has strongly recommended to use this model as a common element in the weekly (or more frequent) analyses. So far, more than half of the relevant analysis centers have switched to this model. This, of course, will also have consequences for the semi real-time EOP solutions which are generated and submitted to IERS for inclusion in the weekly Bulletins A (following the current procedures).

The second project is aimed at quality control of the software that is used within the SLR/LLR community. Its purpose is to benchmark the various computer programs and to detect blunders and other possible problems. It focuses on satellite orbits and specific parameter solutions, which may evolve into (the development of) an official ILRS product for satellite orbits.

The third project focuses on two traditional products, i.e. station coordinates and EOPs. The purpose here is to develop an official ILRS solution, initially for EOP only, but also for station coordinates and/or velocities in the future. Such solutions would be based upon various contributions from different analysis groups. This project initially dealt with procedural and organizational issues at first, and, therefore, used a very limited data set (1 month of LAGEOS-1 data). Since then, it has expanded to cover a full year of LAGEOS-1/LAGEOS-2 data (1999); these are called the „series A" solutions. In March 2001, Etalon-1 and Etalon-2 were added to the data mix, in an attempt to improve the quality of the EOP solutions. At the request of the AWG an intensive tracking campaign for the Etalon pair was organized. Since the analysis results (designated „series B") are not finalized yet, the tracking campaign currently runs until October 2002. The initial results show rather modest improvements in the EOP results. However, some analysis groups are reporting more significant improvements. The earth rotation parameters that are currently solved for include the traditional parameters UT1-UTC and x/y-pole, and their time-derivatives. A summary of the various contributors to this project is given in Table 1.

Of course, the analysis activities within the ILRS, related to IERS, are not restricted to just these pilot projects. The ILRS community is providing input to other projects, like the SINEX Campaign, the EOP Alignment Project and the future (IAG) IGGOS Project. Results on these projects can be found elsewhere.

Table 1: Overview of the various analysis groups that contributed to the series A and B solutions of the AWG pilot project on „positioning and earth orientation".

institute	series A	series B
ASI	+	+
BKG	+	+
CRL	+	+
CSR	+	–
DGFI	+	–
Geosciences Australia	+	+
GRGS	+	–
IAA	+	+
NASA/JCET	+	+
NERC	+	+

Outlook

The AWG pilot projects, that can be considered as the focal point of the ILRS analysis activities, will proceed with the momentum that they have shown so far. For the harmonization project, the results are expected to converge after everyone has switched to the ITRF2000 model (which would take place in 2002). The benchmarking/orbits project has embarked upon a strict and ambitious scheme. Initial results are expected to be presented in October 2002, during another AWG workshop. The project on station position and Earth orientation is entering the stage of an official product combination. A Call for Participation to this extent is scheduled to be released at the same workshop.

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3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

IVS in 2001 held its first biennial Technical Operations Workshop (TOW) at Haystack Observatory, with about 80 participants representing Network Stations, Correlators, and Operation Centers. Two IVS Directing Board meetings were held, one in February at NASA's Goddard Space Flight Center in Greenbelt, MD, USA, and the other in September at the Spanish Research Council in Barcelona, Spain. The second IVS Working Group, called WG2, was established at the February board meeting and charged with reviewing the IVS product specifications and observing programs. The WG2 report was completed and delivered to the board by the end of 2001. The IVS Directing Board received an award from the Japanese Ministry of Public Management, Home Affairs, Post and Telecommunications on June 1, 2001. The award was given for the VSI (VLBI Standard Interface) developed under the auspices of IVS. IVS published the first issue of a newsletter which is intended to keep the community informed about IVS activities.

Network Stations

A total of 909 station days were used in 159 geodetic sessions during the year, for an average of 3.0 days per week observing coordinated by IVS. Observing was increased compared to 2000 due to the increased efficiency of the Mark IV correlators. The major observing programs during 2001 were:

NEOS-A

Weekly 24-hour measurements of EOP were continued by the U.S. National Earth Orientation Service (NEOS), a joint effort of USNO and NASA. Daily 1.5-hour UT1 Intensive measurements continued on the other four days of the week.

CORE

The CORE (Continuous Observations of the Rotation of the Earth) program, coordinated by NASA, observed bi-weekly CORE-3 sessions on the day following NEOS for the first half of the year and then moved to weekly CORE-3 sessions. The CORE-1 (Monday) sessions were monthly. CORE-1 was recorded at 128 Mb/s, double the standard bandwidth, and CORE-3 at 256 Mb/s, quadruple the standard. These modes can only be processed by the Mark IV correlators.

VLBA

The Very Long Baseline Array (VLBA), operated by the National Radio Astronomy Observatory (NRAO), continued to allocate six observing days for astrometry/geodesy. These sessions included the 10 VLBA stations plus up to 10 geodetic stations, providing state-of-the-art astrometry as well as information for mapping ICRF sources.

CRF Five sessions were scheduled for maintenance of the ICRF in the southern hemisphere.

IRIS-S Monthly sessions were coordinated by the Geodetic Institute of the University of Bonn, observed monthly for EOP and TRF determinations.

Europe The European geodetic network, coordinated by the Geodetic Institute of the University of Bonn, continued with three sessions in 2001 due to the termination of EU funding.

APSG The Asia-Pacific Space Geodesy (APSG) program operated two sessions.

JADE The Japanese Domestic Experiments (JADE) had seven sessions. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

Syowa The National Institute for Polar Research (NIPR) continued its sessions that included the Syowa station in Antarctica. The data were recorded with K4 and S2 and processed at the Mitaka (Japan) correlator.

Network Performance

The Network Coordinator's data base of station performance showed data loss of about 12%. The most significant problem in 2001 was RFI (radio frequency interference), which occurs mostly at S-band and is expected to become more severe and widespread in future years.

Correlators

The Mark IV correlators at Haystack Observatory (USA), the U.S. Naval Observatory (USA), and at Max-Planck Institute for Radioastronomy (Germany) became fully operational during 2001. Significant software enhancements and operational improvements were made during 2001, with the final result being 2–3 days processing for each 24-hour session.

Data Centers

The IVS Data Centers continued to receive new data bases throughout the year. Almost all of the historical data bases had been submitted to the Data Centers as of the end of 2001.

Analysis Centers

At the second IVS Analysis Workshop, held at Goddard Space Flight Center in February, participants discussed matters of operational and scientific data analysis. Results of the first IVS Analysis Pilot Project included comparisons of 13 different EOP solutions from 10 Analysis Centers, giving a good indication of the status of the different analysis packages. Outlier detection was added to the combination done by the IVS Analysis Coordinator, increasing the reliability of the results. A call for participation in a second Pilot Project was made in the second half of the year.

Technology Development Centers

The VSI-S (software) specification was nearly completed in 2001. This interface will be the software half of the complete VSI specification. Progress was made toward doing a demonstration experiment for "e-VLBI" in which the raw VLBI data will be transmitted electronically from the stations to the Mark 4 correlator. Participating stations will be Westford (at Haystack Observatory) and the Goddard Geophysical and Astronomical Observatory in Greenbelt, MD. At the Japanese Communications Research Laboratory achievements in high data rate VLBI were made in 2001. They obtained the first real-time fringes at 1 Gbps, and the first tape-based fringes at 2 Gbps.

Nancy Vandenberg, Chopo Ma, Axel Nothnagel

3.4.4 International DORIS Service (IDS)

Overview

DORIS was developed for precise orbit determination and precise positioning on Earth.

Following the inclusion of DORIS as a new technique in IERS, six groups have been participating as Analysis Centres: CNES/SOD, GRGS, and IGN in France, UT/CSR in the USA, DUT in the Netherlands and MCC in Russia. The first four groups have submitted regular results to IERS either for polar motion determination or for tracking stations coordinates and velocities. Other groups are still developing their processing capabilities. Two IERS Data Centres have been providing the scientific community with DORIS measurements for several years: NASA/CDDIS and IGN/LAREG.

In 1999, following the recent IERS reorganization, it has been decided at the IAG General Assembly (Birmingham, UK, August 1999) to create a DORIS Pilot Experiment. Such a Pilot Experiment would give time to all groups to coordinate and improve their operationability in order to create on the long term an International DORIS Service (IDS). In the future, this scientific service would structure the DORIS community in order to provide scientific products for a broad range of potential users, starting by the IERS itself. This is done as common activity of the IERS and the IAG/CSTG (Commission of the International Association of Geodesy for the Coordination of Space Technique). This is very similar to what is done for GPS by the IGS, or for VLBI by the IVS or for SLR and LLR for the ILRS. The Steering Committee manages the DORIS Pilot Experiment with the help of a Central Bureau responsible for the daily coordination and management: information, communication, meetings, workshops…

After two DORIS Days meetings held in 1998 and 2000, the DORIS community will meet at the first IDS Workshop in Biarritz, France, in June 2002.

Two Data Centres support DORIS data and products archiving and distribution activities for the space geodesy and geodynamics community.

The Central Bureau started a station coordinates Analysis Campaign in November 2001 and Martine Feissel-Vernier joined the Steering Committee as Analysis Coordinator.

The DORIS Station Selection Committee define site criteria and analyse proposals for new sites. As a first experiment, Geoscience Australia installed a DORIS beacon in Antarctica in December 2001 to be operated for a few weeks.

For two years, a network renovation action has been conducted: today almost half of the stations meet the new stability requirement. In the same period, third generation beacons were developed. Deliveries and deployment started in December 2001.

A new satellite recently joined the three satellites already flying with a DORIS receiver, two other will be launched in early 2002. They carry an improved second generation DORIS receiver including two channels and DIODE navigator.

The International DORIS Pilot Experiment

For the DORIS Pilot Experiment an international Call for Participation has been issued in September 1999. A Steering Committee has been set up and is now composed of the following individuals:

Gilles TAVERNIER	CNES	Chairperson
Martine FEISSEL-VERNIER	Observatoire de Paris-IGN	Analysis coordinator
Frank LEMOINE	NASA/GSFC	Stations Selection Group chairperson
Carey NOLL	NASA/CDDIS	Data Flow coordinator
John RIES	University of Texas CSR	future DORIS representative to IERS
Laurent SOUDARIN	CLS	Central Bureau Web server
Pascal WILLIS	IGN-JPL	DORIS representative to IERS

CNES, CLS and IGN perform the operational tasks of the Central Bureau. A specific Web site has been created presenting the Pilot Experiment organization, the proposals, the members of the different groups, the DORIS Mails, the Site logs, a lot of new information on the DORIS system and also links to all DORIS groups Web sites: <http://ids.cls.fr>

An IDS Workshop will be held in Biarritz on June 13 and 14, 2002, dealing with general information about the DORIS system evolutions (satellites, network…), IDS status (central bureau, stations selection group, data centres), orbits and related products, DORIS analysis results (plate motions, vertical velocities, EOP, TRF…) and the IDS analysis campaign.

Two Data Centres archive and distribute DORIS measurements and ancillary data. They will also archive and distribute products as soon as they are available, with the help of Carey NOLL (Data Flow coordinator):

NASA GSFC / CDDIS	USA	Carey Noll
IGN / LAREG	France	Edouard Gaulué

Data are currently available for 4 satellites for more than 12 years:

- SPOT2: from 31 March to 04 July 1990, from 01 February to 22 March 1992 and from 16 October 1992
- TOPEX/POSEIDON: from 25 September 1992
- SPOT3: from 01 February 1994 to 09 November 1996
- SPOT4: from 01 May 1998

Data from the recently launched JASON will be available soon.

There are eleven candidate Analysis Centres willing to process DORIS measurements:

AUSLIG	Australia	Ramesh Govind
CNES	France	Jean-Paul Berthias
CSR the Univ. of Texas	USA	John Ries
ESA ESOC Darmstadt	Germany	John Dow
Geod. Observ. Pecny	Czech Rep.	Jan Kostelecky
IAA St Petersbourg	Russia	George Krasinsky
IGN LAREG	France	Pascal Willis
INASAN Moscow	Russia	Suriya Tatevian
LEGOS / CLS	France	Jean-François Crétaux
Royal Observ. of Belgium	Belgium	René Warnant
University of Newcastle	UK	Phil Moore

The IDS Central Bureau initiated in November 2001 an Analysis Campaign that originally focused only on sets of station coordinates derived from the June 2001 observations of the Spot2, Spot4 and Topex/Poseidon satellites.

The main objectives of the campaign are as follows:

- Check the level of consistency of results obtained using different software packages
- Identify and analyse possible systematic discrepancies
- Study the possibility of defining time series of sets of station coordinates as an IDS product
- Initiate the process of combining DORIS results into unified IDS products.

Responses were received from six Analysis Centres, while three other expressed interest to participate at a later time. The content of the responses was larger than expected, in several ways: the data span covers several years, as compared to the single month requested, and the products span not only sets of stations coordinates, but also times series of the Earth Orientation Parameters and of the geocentre location and orbits.

Martine Feissel-Vernier joined the Steering Committee as Analysis Coordinator.

In order to extend the comparison capabilities, a number of colleagues accepted to participate in their field of expertise. To date, the following analysts have accepted to participate:

Sets of station coordinates:

- L. Soudarin, J.-J. Valette, CLS and Z. Altamimi, IGN

Satellite orbits:

- H. Boomkamp, ESA

EOP time series:

- D. Gambis, IERS Earth Orientation Centre
- J. Ray, IERS Rapid Service/Prediction Centre
- M. Rothacher, IERS Analysis Coordinator

The Stations Selection Group chaired by Frank LEMOINE includes scientists involved in various applications such as geodesy, geophysics, altimeter calibration, tide gauges, ITRF collocation and a representative of the DORIS Stations Installation and Maintenance Service (IGN/SIMB): Eric CALAIS, Chuck DE METS, Herve FAGARD, Ramesh GOVIND, Bruce HAINES, Kristine LARSON, Seth STEIN, Simon WILLIAMS.

The group defined site criteria taking DORIS site constraints into account and prepared a Station Response Form which was sent to candidate sites.

Currently complete (i.e. Site Survey Forms and Documentation available) proposals are:

1. Wousi, New Hebrides	form, photo	Contact: Stéphane Calmant
2. Wettzell, Germany	form	Contact: Wolfgang Schlüter
3. Chile (TIGO)	form, e-mail	Contact: Wolfgang Schlüter
4. O'Higgins,Antarctica	form	Contact: Wolfgang Schlüter
5. Czech Republic	form, various pictures	Contact: Jan Kostelecky
6. Brussels	form, e-mail, photos	Contact: René Warnant
7. San Fernando, Spain	form	Contact: Jose Martin Davila
8. Gavdos, Crete	form	Contact: Stelios Mertikas
9. AUSLIG Cape York, Northern Australia Burnie, Tasmania Lambert, Antarctica	email	Contact: Ramesh Govind
10. Svetloe, Russia	form, photos	Contact: Zinovy Malkin

Incomplete proposals:

1. Iran e-mail, picture		Contact: Faramarz Nilforousan
2. Northwestern India		Contact: Vinod Gaur

During the 12th December 2001 to 5th February 2002 period, Geoscience Australia (formerly Australian Surveying and Land Information Group, AUSLIG) deployed a DORIS beacon on the Sorsdal Glacier, which is located in the vicinity of the Davis Station (68°S–78°E), Australian Antarctic Territory. It is the first site selected for the IDS DORIS Pilot Experiment (see a short report at <http://www.jason.oceanobs.com/html/applications/ice/doris_sorsdal_uk.html>).

Complete information about the activities of the Stations Selection Group are available on its web page which can be found on the IDS web site or directly at the following address:

<http://phys-geophys.colorado.edu/~kristine/doris.html>

DORIS Network

As in the past years, the DORIS network has been very stable (see Figure 1). The installation and maintenance activities are realized by the IGN/SIMB.

Figure 1: The DORIS Network

In order to reach new accuracy goals for JASON 1 and ENVISAT, it was decided to improve the long-term stability of the antennas when necessary.

This network renovation action started in 2000 with the stations of Cibinong, Djibouti, Hartebeesthoek and Metsahovi. Two new stations were installed in Greenbelt, replacing Ottawa (antenna on a concrete pillar instead of a high building) and in Futuna (antenna on an iron tube + concrete), replacing Wallis. Several new local ties with other geodetic techniques were measured and transmitted to the IERS Central Bureau. 11 stations were renovated in 2001: Rio Grande, Easter Island, Santiago, Amsterdam, Kerguelen, Kitab, Ponta Delgada, Yellowknife, Arequipa, Noumea and Chatham, and one new station was installed at Mahe, Seychelles. Several other renovations are under way. Almost half of the stations (21 “excellent” and 4 “good”, out of 54 stations in total) meet the new stability requirement, to be compared with 1 out of 6 two years ago.

It was also decided to develop third generation beacons to improve DORIS system accuracy and capacity, with possible frequency shift avoiding jamming by nearby stations, higher transmitted power, a modulated 2 GHz channel and possible remote control through a telephone line or an Argos terminal. Such a beacon has already been installed in Toulouse (master beacon). Other upgrades are planned in 2002, such as in the French Southern Indian Ocean territories.

Sites logs have been created by the SIMB for all DORIS sites and are available at the IGN Web site (<http://www.ign.fr/fr/PI/activites/geodesie/DORIS/stations-en.html>. This includes information concerning the changes in the DORIS ground equipment (antenna, beacon...) and also precise local ties with other precise space technique of the IERS. Among the existing 54 stations of the DORIS network, 35 are collocated with other techniques: 34 with 12 SLR (of which 6 permanent SLR) and 13 with VLBI (of which 7 permanent VLBI). The 4 techniques are collocated on 6 sites.

Collocation with tide gauges is also important for altimetry missions: 17 DORIS stations are less than 10 km from a GLOSS tide gauge and new sites will be selected in order to increase this number.

DORIS Control Centre

SSALTO, the new DORIS and altimetry multimission Control Centre is operational since December 2000. Thanks to its links with the Control Centres of the different satellites fitted out with a DORIS receiver, it is able to collect DORIS measurements, preprocess and send them to the DORIS Data Centres as well as ancillary data such as manoeuvres, attitude, meteorological data.

SSALTO also produces preliminary and precise orbits, which will be sent to the Data Centres as soon as a format is adopted. The AVISO component will ensure archiving.

DORIS Satellite Constellation

First generation receivers equipped four satellites: SPOT 2 (launched in 1990), TOPEX/POSEIDON (launched in 1992), SPOT 3 (1993–1996) and SPOT 4 (launched in 1998).

Second generation DORIS receivers have a dual channel capability, allowing multiple stations positioning in the same area, an improved accuracy and a real autonomy thanks to DIODE navigator: self start, self programming and real time on-board orbit determination.

One satellite carrying such a receiver has been recently launched:

- JASON 1 was launched December 7, 2001, the DORIS receiver was switched on December 8 and automatically started without any command from the ground thanks to DIODE. The orbit accuracy is already on the TOPEX/POSEIDON level and should reach the aimed at radial centimetre level. The real time on-board radial accuracy is 9 to 16 centimetres RMS.

Two other satellites carrying such a receiver will be launched soon:

- ENVISAT in February/March 2002
- SPOT 5 in April/May 2002

New satellites will be launched in the future, such as CRYOSAT (ESA), JASON-2 or Pleïade (SPOT follow-on).

Furthermore, in its proposal CNES has offered receivers for possible new missions. The number of available DORIS satellites has been a limiting factor in the accuracy of the DORIS results for IERS (stations positions and velocities), polar motion, for a long time. This situation should improve in the near future thanks to the three new satellites in space, but it is important to go on increasing the number of satellites.

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3.5 Product Centres
3.5.1 Earth Orientation Centre

This section presents activities and main results concerning the Earth Orientation Centre located in Paris Observatory over 2001. General presentation of the IERS Earth Orientation Parameters (EOP), operational activities and yearly analyses are presented in the web site <http://hpiers.obspm.fr/eop-pc>. According to the IERS terms of reference, the Earth Orientation Centre is responsible for monitoring Earth Orientation Parameters including long term consistency, publications for time dissemination and leap second announcements. It is making available to users different products: long-term series of Polar Motion, Universal Time (UT1) and Length of Day (LOD), and operational solutions including real-time estimates and predictions.

Determination of EOP is in the form of combined solutions derived from the individual series. Various solutions are computed: long-term solution (IERS C01), normal values at five and one-day intervals (IERS C02 and C03) and the operational smoothed solutions at one-day intervals in Bulletin B published with a delay of thirty days between the date of publication and the last date of the standard solution. Bulletin B is updated in the IERS C04 computed twice weekly.

Combined daily series: Bulletin B and EOP(IERS) C 04

Description of Bulletin B is available in the IERS Explanatory Supplement for Bulletin A and Bulletin B (Gambis and Ray, 2001). Table 1 gives the estimated uncertainties of the individual solutions entering the combination for 2001 after removal of systematic variations. Formal uncertainties reported by the contributors are often under-estimated. They are calibrated by statistical assessment using the Allan variance analysis in order to reflect the real quality of the data (Gray and Allan, 1974; Gambis, 2002). This procedure leads to an optimal weighting.

Predictions

Different approaches are used for prediction of the Earth Rotation Parameters.

Polar Motion

The formalism uses at first a floating period fit (Bevington, 1969) for both the Chandler and annual components estimation over a past time interval of several years. An autoregressive filter is then applied on the short-term residuals series and used for the prediction. The predictions of the nutation offsets $d\psi$ and $d\varepsilon$ are based on an empirical model (McCarthy, 1996).

Universal Time

The present formalism used is based on the assumption that the long-term fluctuations (annual and semi-annual) of the preceding year are valid over the next few months. For short-term variations prediction, an autoregressive process is used. Table 2 shows the current accuracy of the EOP solutions and also the skills of the predictions. New procedures for prediction are under investigation, they are based on Singular Spectrum Analysis SSA and Neuronal networks.

Table 1: Estimated accuracies of the different solutions entering the combined solutions.

Individual solutions		Estimated uncertainties				
		Time	Terrestrial Pole 0.001"	UT1 (0.0001s)	LOD (0.0001s)	Celestial Pole 0.001"
VLBI – 24 h						
EOP (AUS)	01 R 01	7d	0.14	0.04		0.09
EOP (BKG)	00 R 02	7d	0.14	0.06		0.10
EOP (GSFC)	01 R 04	7d	0.15	0.05		0.12
EOP (IAA)	02 R 01	7d	0.11	0.03		0.09
EOP (SPBU)	00 R 03	7d	0.11	0.04		0.09
VLBI – Intensive						
EOP (BKG)	00 R 01	1–3 d		0.13		
EOP (GSFC)	01 R 03	1–3 d		0.14		
EOP (IAA)	02 R 02	1–3 d		0.11		
EOP (SPBU)	99 R 01	1–3 d		0.14		
Satellite Laser Tracking						
EOP (CGS)	97 L 02	3d	0.26	0.30 *		
EOP (CSR)	95 L 01	3d	0.44	0.27 *		
EOP (DUT)	98 L 01	3d	0.15	0.09 *		
EOP (IAA)	98 L 02	1d	0.08	0.03 *	0.03	
EOP (MCC)	97 L 01	3d	0.07		0.10	
GPS						
EOP (CODE)	98 P 01	1d	0.02	0.01 *	0.30	
EOP (EMR)	96 P 03	1d	0.07	0.23 *	0.08	
EOP (ESOC)	96 P 01	1d	0.03	0.03 *	0.03	
EOP (GFZ)	96 P 02	1d	0.02	0.02 *	0.02	
EOP (JPL)	96 P 03	1d	0.05	0.16 *	0.16	
EOP (NOAA)	96 P 01	1d	0.04	0.10 *	0.19	
EOP (SIO)	96 P 01	1d	0.11	0.55 *	0.20	

** The satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodelled orbit node motion. VLBI-based results have been used to minimize drifts in UT estimates.*

Table 3 gives the agreement and consistencies of the IERS C04 solution with two combined solutions obtained by the IERS rapid service at USNO and the JPL. These values reflect the mean precision reached i.e. about 0.05 mas for polar motion and 10 microseconds for UT1. The overall accuracy taking into account the consistency between the terrestrial and celestial frames is in the range of 0.1 mas and 20 microseconds, respectively for Polar motion and UT1.

Table 2: Uncertainty of the current solution for 2001 and the estimated accuracies of the predictions for horizons of 5 days to 2 years.

Solutions		Terrestrial Pole 0.001"	UT1 0.0001s	Celestial Pole 0.001"
Analysis	1–d	0.1	0.2	0.3
Prediction	5–d	1.6	6.0	0.3
	10d	3.0	16.	0.3
	30d	10.	40.	0.3
	90d	30.	30.	0.3
	180d	60.	55.	0.3
	1-yr	30.	100.	0.3

Table 3: Mean and standard deviation of the differences between various IERS solutions for 2001

EOP	Unit	SPACE 2001 – IERS C04		NEOS final – IERS C04	
		Mean	Standard deviation	Mean	Standard deviation
X	mas	–0.08	0.04	0.04	0.05
Y	mas	–0.02	0.04	0.07	0.05
UT1	0.1 ms	0.05	0.10	0.02	0.20
$d\psi.\sin\varepsilon$	mas	–	–	–0.15	0.48
$d\psi$	mas	–	–	–0.04	0.31

Long-term series: C 01 (1846–2001)

EOP(IERS) C 01 is a series of the Earth Orientation Parameters given at 0.1 year interval from 1846 to 1889 (polar motion only) and 0.05 year interval from 1890 until now (polar motion, celestial pole offsets; UT1–UTC since 1962). For many decades, the observations were made using mostly visual and photographic zenith telescopes. Since the advent of the space era in the 1960s, new geodetic techniques were used for geodynamics. Now, the global observing activity involves Very Long Baseline Radio Interferometry (VLBI), Lunar (LLR) and Satellite Laser Ranging (SLR), Global Positioning System (GPS) and more recently DORIS.

The C 01 series was recomputed in the course of 2001 to take into account, from 1900 to 1961, the series recomputed by J. Vondrak (1995) based on the processing of optical data using Hipparcos catalogue as the celestial frame. The C01 series is a composite series based on the following solutions:

1846–1899: Fedorov *et al*. (1972) polar motion solution derived from three series of absolute declination programs (Pulkovo, Greenwich, Washington).

1900–1961: Vondrak *et al.* (1995) solution derived from optical astrometry analyses based on the Hipparcos reference frame. The series gives polar motion, celestial pole offsets and Universal Time (since 1956).

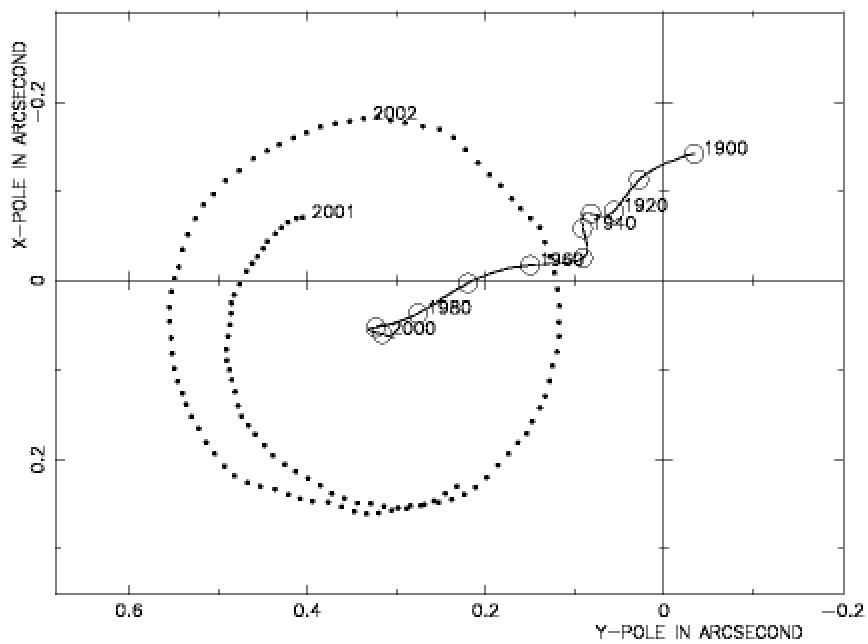
1962–2001: BIH and IERS solutions (BIH and IERS Annual Reports).

Mean Pole with respect to the IERS reference origin

The analyses of the observations of space geodesy require to perform the transformation between both terrestrial and celestial frames via the Earth orientation parameters. Gravity field models include the tesseral coefficients C21 and S21 coefficients. These terms describe the position of the Earth's figure axis with respect to the Terrestrial Reference Frame. This axis should coincide with the observed position of the rotation pole averaged over the same time period.

The mean polar motion is affected by a long-term drift westward (direction 70.7 deg west, rate: 4.2 mas/year). The mean rotation axis with respect to the IERS Terrestrial Reference Frame, can be considered as the long-term trend obtained after filtering out the Chandler and seasonal terms, every year from 1900 to 2000 (Shiskin *et al.*, 1965). Figure 1 represents the polar motion over 2001–2002 and the path of the mean pole since 1900. The table is available in Conventions 2000 (McCarthy, 2002) and at the following address: <http://hpiers.obspm.fr/eop-pc/>

Figure 1: Mean polar motion (1900–2001) and IERS C04 polhody over 2000–2001.



Middle-term Solution: C 02 (1962–2001), C 03 (1993–2001)

Other series, based on normal points solutions given at various time intervals, are also proposed to users, i.e. C 02 (5-day intervals, polar motion, UT1–UTC, $d\psi$, $d\varepsilon$), C 03 (one-day intervals, polar motion, UT1–UTC) (Gambis, 1996; Eisop and Gambis, 1997). These series are respectively consistent one to another. They use the full correlation matrix when available. Recently there were new developments in the normal point series C 02 and C 03 in which the estimation of the solution given at the central dates of the n-day interval is made using a least-square fit for all EOP components. Although the L2 estimation has been extensively used for data analysis, it has some drawbacks linked to problems of ill-conditioning and in the non-detection of outliers. Alternative methods based on robust estimators like M-Huber can be used. These estimators are a generalization of both the L1 and L2 class. They have been implemented in our analyses and are now currently used (Bougeard *et al.*, 2000; Gambis *et al.*, 2002). Table 4 gives the evolution of the mean uncertainties of C02 solution since 1962.

Table 4: EOP(IERS) C 02 : Average uncertainty of the normal point solution given at five-day intervals

YEARS −− Unit	σ(X) −− 0.001"	σ(Y) −− 0.001"	σ(UT1) −− 0.0001s	$\sigma(d\psi)$ −− 0.001"	$\sigma\,(d\varepsilon)$ −− 0.001"
1962–1967	30	30	20	–	–
1968–1971	25	25	17	–	–
1972–1979	11	11	10	–	
1980–1983	2	2	3	2	1
1984–1989	.4	.4	.2	.5	.3
1990–2000	.2	.2	.15	.3	.2
2001–2002	.1	.1	.10	.3	.2

Consistency of IERS EOP series with ITRF and ICRF

Individual EOP series determined from the analyses of the various techniques present mutually systematic errors, generally limited to biases and drifts which can be attributed to the adoption of different reference frames CRF and TRF. Monitoring of the consistency is currently performed at the Earth Orientation Centre in the IERS Annual Reports since 1991. Note that the mean consistency is regularly improving with years for the different techniques (Figures 2 to 4). This reflects both the improvement in the EOP accuracy and the better determination of reference frames ties. So far, the mean estimated values are about 0.1 mas for polar motion and 20 microseconds for UT1 (IERS Annual Reports).

Figure 2: Evolution of VLBI solutions since 1991

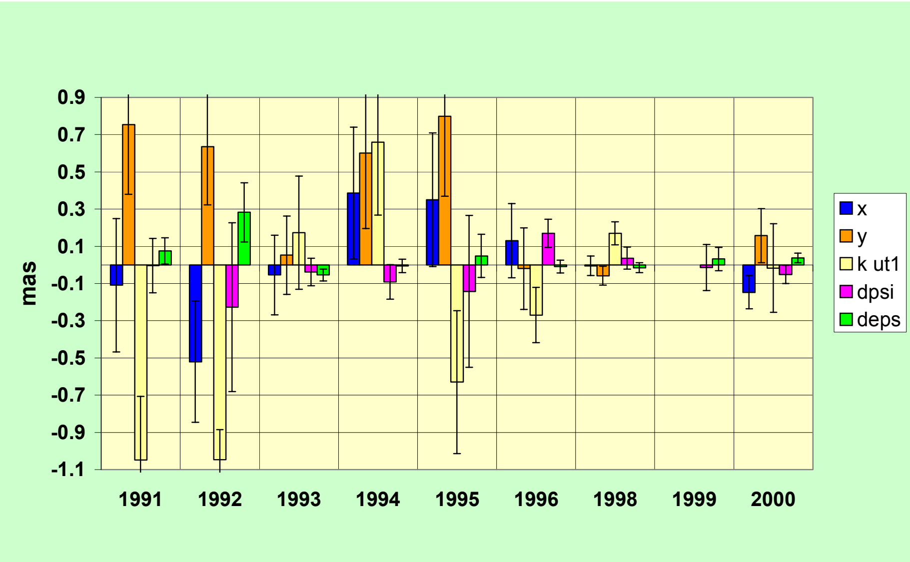
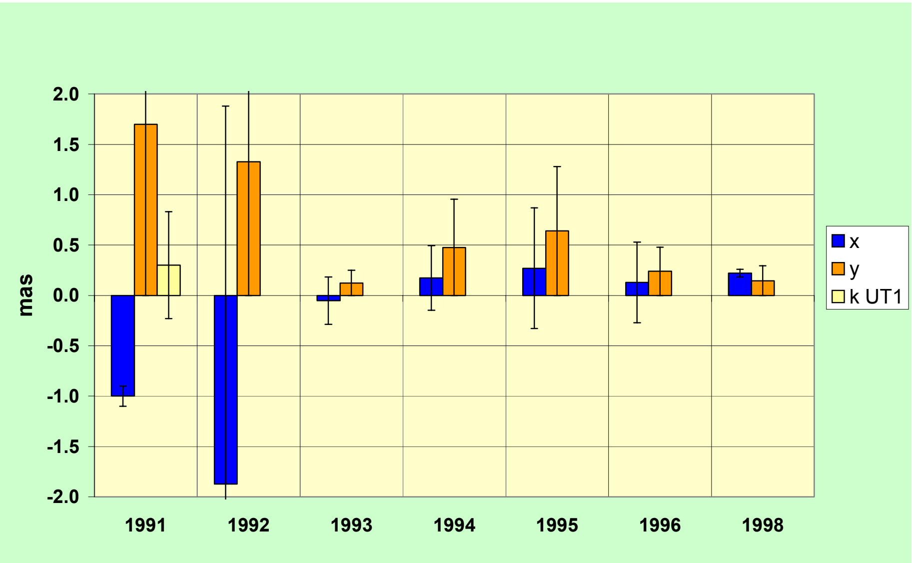


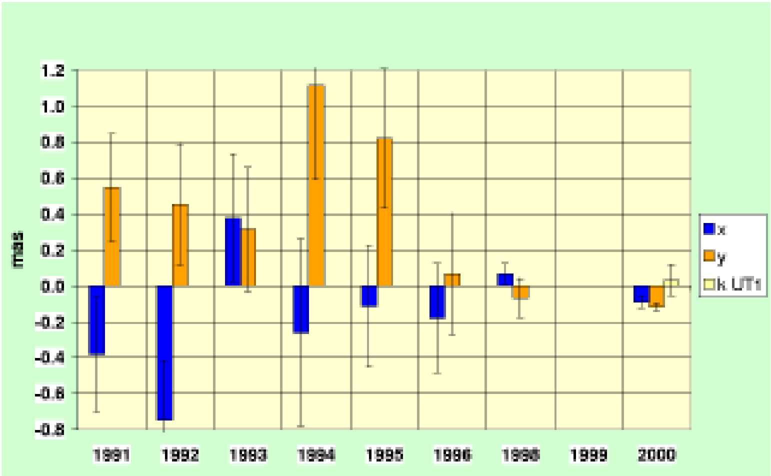
Figure 3: Evolution of GPS solutions since 1991



There are different approaches to estimate the consistency of the IERS EOP system with respect to both terrestrial and celestial reference frames.

The usual method performed at the IERS consists in comparing the individual EOP solutions to the IERS C04 after estimation of the rotation angles between on one hand the individual CRF with respect to ICRF and on the other hand the individual TRF with respect to ITRF. The basic formalism is described in Zhu and Mueller (1983) and in the IERS Annual Reports. Figures 2 to 4

Figure 4: Evolution of SLR solutions since 1991



represent, since 1991, the evolution of the unconsistency for the different techniques VLBI, GPS and SLR (Bizouard and Gambis, 2002). Note that the mean unconsistency is for the various techniques at the level of 0.1 mas for polar motion and 20 microseconds for UT1. This approach is so far not straightforward since due to constraints introduced in the determination of the terrestrial and celestial frames, angles between the individual TRF and the ITRF cannot be easily computed.

A more satisfying method to monitor the consistency, so far not realized within the IERS is based on a rigorous computation of both frames, CRF, TFR and EOP parameters.

An intermediate approach consists in assessing the systematic corrections between individual EOP solutions obtained through the analyses of the data of the various techniques, mostly VLBI and GPS in which both reference frames were constrained to ICRF-Ext1 and ITRF2000 (Altamimi et al., 2002). We have performed such comparisons with respect to the combined IERS C04 solution using the results obtained by the VLBI analysis centres for the IVS Pilot Project in 2001. We have also used comparisons of GPS solutions which are since December 2001 computed in the ITRF2000 frame which does not present any significant rotation with ITRF97 (Gambis et al., 2002). IVS Pilot 2001 EOP solutions are compared to the IERS C04 used as the reference: Significant systematic differences appearing between these individual series of both techniques and C04. Eleven analysis centres submitted EOP series for the second IVS pilot project. These series were derived from all available NEOS-A 24hr VLBI sessions over 1999 and 2000. In these solutions, the celestial and the terrestrial reference were held fixed respectively to ICRF-Ext1 and to ITRF2000 with the associated velocity field.

Estimated parameters include the pole components X-Pole, Y-Pole, UT1–UTC and the nutation offsets dPsi, dEps with respect to IAU 1980 model. The individual VLBI series are compared to IERS C04 together with the operational GPS series also referred to ITRF2000. Tables 5 and 6 give the statistics concerning the systematic biases and the mean values. For X-Pole the unconsistency is negligible, whereas for Y-Pole it is 0.326 mas (VLBI) and 0.188m (GPS).

In conclusion, it appears that there is a slight unconsistency in the IERS C04 y-pole solution of about 0.1 – 0.2 mas with respect to ICRF-Ext1 and ITRF2000. However its value is of the same order as the discrepancy between VLBI and GPS solutions (0.150 mas).

Table 5: Systematic biases of VLBI EOP series compared to IERS C04 used as the reference

VLBI	AUS	BKG	CAN	DGFI	GSFC	IAA	IGG	JPL	OSO	OSO2	SPBU	Mean*	rms
xpole(mas)	-.058	-.016	-.094	-.114	-.055	-.143	-.161	-.220	.062	.055	-.086	-.060	.076
ypole(mas)	.367	.330	-.403	.312	.328	.286	.319	.696	.330	.311	.347	.326	.024
UT1(µs)	6	8	7	8	8	6	10	13	14	16	7	9	3.4
deps(mas)	.028	-.090	.036	51.467	.009	-.015	51.372	.851	-.096	-.108	.031	-.012	.058
dpsi(mas)	049	.043	.000	5.519	.021	.086	5.512	-2.764	.096	.116	.038	.048	.034

* CAN and JPL are excluded for polar motion; DGFI, IGG and JPL for nutation

Table 6 : Systematic biases of GPS EOP series compared to IERS C04 used as the reference

GPS	CODE	JPL	GFZ	ESOC	NOAA	SIO	EMR	Mean	rms
xpole(mas)	-020	-.047	-.070	-.029	-.085	-.039	-.023	-.045	.024
ypole(mas)	.186	.180	.184	.257	.158	.207	.148	.188	.036
LOD (µs)	8	-7	-5	-33	-29	0	-19	-12	15

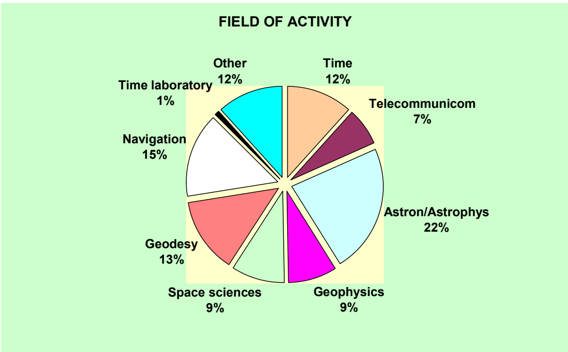
Survey for a possible UTC re-definition

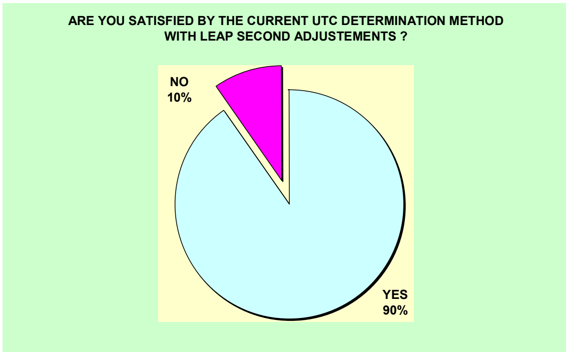
UTC (Coordinated Universal Time) is computed from TAI by the introduction of leap seconds such that UTC is maintained within 1 second of UT1. Since 1972, these leap seconds have been added on December 31 or June 30, at the rate of about one every 18 months. The relevant bulletins are:

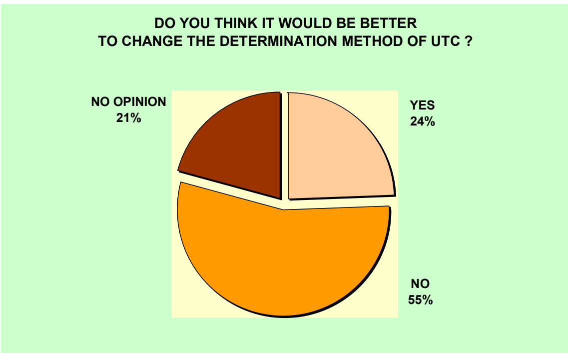
Bulletin C, Announcement of the leap seconds in UTC.

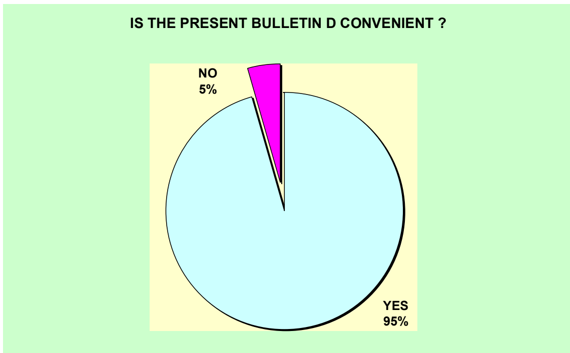
Bulletin D, Announcement of the value of DUT1 truncated at 0.1s for transmission with time signals.

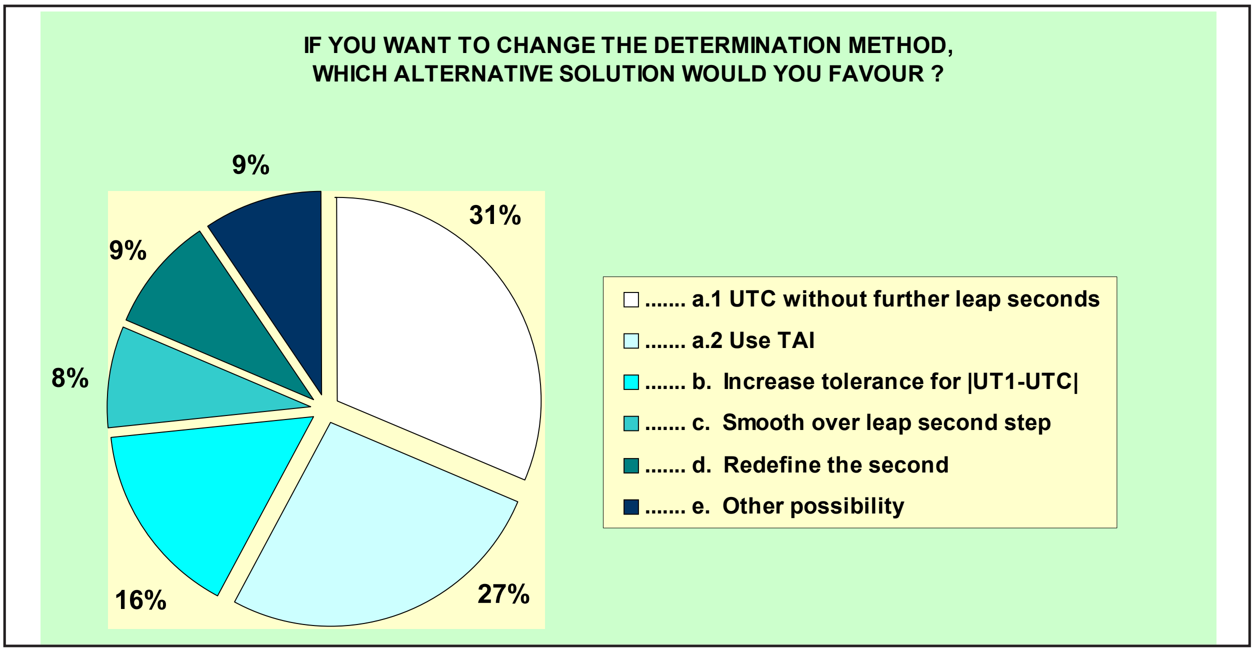
Recently, some communities linked to telecommunications and navigational systems have proposed a revision of the definition of UTC to avoid the discontinuities due to the intermittent leap seconds. The Earth Orientation Centre is responsible for prediction and announcement of the leap second (Bulletin C) and the announcement of the value of DUT1 truncated at 0.1s for transmission with time signals. It was thus of prime importance to question the users of Bulletins C and D to survey opinion concerning a possible redefinition of UTC. The questionnaire was sent via e-mail and also by usual airmail to about one thousand users altogether. 247 reponses were received and processed in Summer 2002. The main results and statistics are given in the following diagrams.











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3.5.2 Rapid Service/Prediction Centre

Rapid Service Techniques

The algorithm used by the IERS Rapid Service/Prediction Centre for the determination of the quick-look Earth orientation parameters is based on a weighted cubic spline with adjustable smoothing fit to contributed observational data (McCarthy & Luzum, 1991a). Contributed data are corrected for possible systematic differences. Biases and rates are determined with respect to the C04 system of the IERS Earth Orientation Centre (EOC). Statistical weighting used in the spline is proportional to the inverse square of the estimated accuracy of the individual techniques. Minimal smoothing is applied, consistent with the estimated accuracy of the observational data.

Weights in the algorithm may be either an a priori values estimated by the standard deviation of the residual of the techniques or based on the internal precision reported by contributors. Estimated accuracies of data contributed for rapid service estimates of Earth orientation are shown in Table 1.

Table 1. Estimated accuracies of the techniques in 2001. Units are milliseconds of arc for x, y, dψ, and dε and milliseconds of time for UT1-UTC and LOD.

Contributor	Estimated Accuracy					
	X	Y	UT1	LOD	dψ	dε
CSR 3-day SLR	0.5	0.5	0.12*			
DUT 3-day SLR	0.4	0.4				
IAA 1-day SLR	0.2	0.2				
MCC 1-day SLR	0.2	0.2				
GSFC daily VLBI			0.028			
SpbU daily VLBI			0.027			
GSFC weekly VLBI	0.3	0.3	0.010		0.4	0.1
IAA weekly VLBI	0.2	0.2	0.007		0.4	0.1
Texas LLR (CERGA)			0.15			
Texas LLR (MLRS2)			0.15			
IGS Final	0.06	0.06				
IGS Rapid	0.08	0.08		0.02*		
USNO GPS UT*			0.015*			
EMR GPS UT*			0.03*			
USNO AAM UT**			0.036**			

* All satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodeled orbit node motion. VLBI-based results have been used to correct for LOD biases and to minimize drifts in UT estimates.
** Estimated accuracy at time of solution epoch for issues after 14 August 2001.

Operationally, the weighted spline uses as input the epoch of observation, the observed value, and the weight of each individual data point. The software computes the spline coefficients for every data point which are then used to interpolate the Earth orientation time series so that x, y, UT1-UTC, $d\psi$, and $d\varepsilon$ values are computed at the epoch of zero hours UTC for each day. The only data points that are excluded from this process are points whose errors, as reported by the contributors, are greater than three times their average reported precision or those points that have a residual that is more than four times the associated a priori error estimate. Since all of the observations are reported with the effects of sub-daily variations removed, no processing is done to account for these effects (see IERS Gazette No. 13, 30 January 1997).

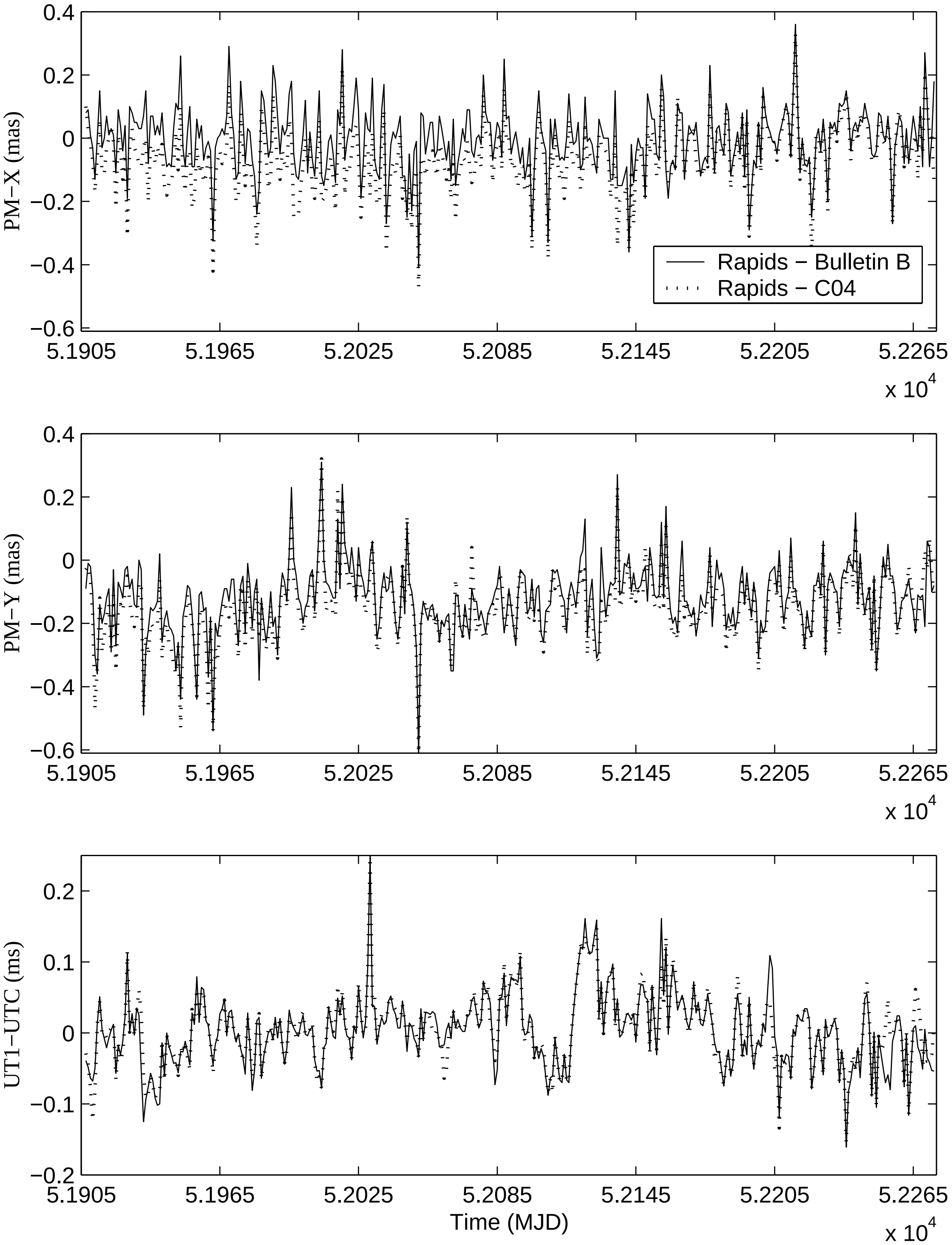
Table 2. Mean and standard deviation of the differences between the various Rapid/Prediction Centre solutions and IERS Bulletin B and C04 EOP solutions for 2001. Polar motion X and Y values are in units of mas and UT1-UTC values are in units of ms.

	Bulletin A – Bulletin B		Bulletin A – C04	
	Mean	Std. Deviation	Mean	Std. Deviation
Bulletin A Rapid Solution (Twice Weekly)				
X	0.00	0.11	-0.06	0.11
Y	-0.12	0.11	-0.15	0.11
UT1-UTC	0.002	0.051	0.004	0.049
Bulletin A Daily Solution				
X	-0.01	0.16	-0.07	0.16
Y	-0.10	0.18	-0.13	0.18
UT1-UTC	0.004	0.077	0.005	0.076
Running Solution (finals.data)				
X	0.00	0.06	-0.06	0.06
Y	0.00	0.05	-0.03	0.04
UT1-UTC	-0.004	0.022	0.002	0.021

The daily values errors listed in Bulletin A are derived from the quality of the spline fit in the neighborhood of the day in question. Table 2 shows the accuracies of three different Rapid/Prediction Centre products compared to the series Bulletin B and C04 maintained by the IERS EOC at the Paris Observatory. The agreement between the twice weekly Bulletin A Rapid solution and the daily Bulletin solution with the IERS EOC solutions are quite good, except for the large mean values for the Y-component of polar motion. An examination of the differences between the twice weekly rapid solutions also indicates that the Y-component of polar motion has an offset from the both the Bulletin B and C04 solutions (Figure 1). This offset, for the Y-component of polar motion, appears to be the result of IGS EOP files being used in the combination solution software. Fortunately, the introduction of the new IGS

Final EOP file corrected this problem, as described later in this section. This error does not exist in the Rapid Service/ Prediction Centre's running EOP solution. Overall, the EOP estimated for both the Bulletin A rapid solution and daily solution have similar accuracies at the time of solution epoch.

Figure 1: Differences between Bulletin A Rapid Solutions and the Earth Orientation Parameters available in Bulletin B and C04



Prediction Techniques

Polar motion predictions are based on the extrapolation of an annual and semiannual ellipse and a Chandler circle fit to the previous 1100 days of observed values of x and y (McCarthy and Luzum, 1991b). The differences between the last observed pole position and rate and those of the curve are computed. These differences are then used to adjust the extrapolated curve by an amount that decreases with the length of the forecast. In February 1998, the near-term polar motion predictions (less than about 30 days) were improved significantly by modifying the transition process from the last observed polar motion result to the long-term predictions. Continuity in the first derivatives was enforced placing great weight on the observed polar motion rate reported by the IGS in their Rapid series. The improvement was most pronounced for the shortest prediction intervals. The procedure for UT1-UTC involves a simple technique of differencing (McCarthy and Luzum, 1991b). All known effects such as leap seconds, solid Earth zonal tides, and seasonal effects are first removed from the observed values of UT1-UTC. Then, to determine a prediction of UT1-UTC n days in the future, $(UT1\text{-}TAI)_n$, the smoothed time value from n days in the past, $\langle(UT1R\text{-}TAI)_{-n}\rangle$ is subtracted from the most recent value, $(UT1R\text{-}TAI)_o$.

$$(UT1\text{-}TAI)_n = 2(UT1R\text{-}TAI)_o - \langle(UT1R\text{-}TAI)_{-n}\rangle.$$

The amount of smoothing used in this procedure depends on the length of the forecast. Short-term predictions with small values of n make use of less smoothing than long-term predictions. Once this value is obtained, it is possible to account for known effects in order to obtain the prediction of UT1-UTC. This process is repeated for each day's prediction.

The very near-term UT1-UTC prediction is strongly influenced by the observed daily Universal Time estimates derived at USNO from the motions of the GPS orbit planes reported by the IGS Rapid service. The IGS estimates for LOD are combined with the GPS-based UT estimates to constrain the UT1 rate of change for the most recent observational day. For the 5 days after the latest observed day, AAM-based predictions of LOD excitation are combined smoothly with the longer-term UT1 predictions described above.

Errors of the estimates are derived from analyses of the past differences between observations and the published predictions. Formulas are published in Bulletin A to extend the tabular data. The prediction of $d\psi$ and $d\varepsilon$ is based on the KSV_1996_3 model (McCarthy, 1996). Table 3 and 4 show the mean magnitude and the standard deviation of the differences between the daily solution and C04 solution, respectively, for 2001. Recent prediction performance in UT1-UTC has been improved by 42% at 10 days into the future by the addition of a UT1-like data product derived from NCEP AAM (UTAAM) to the combination and prediction routine. This estimate of improvement was determined by examining one year of daily solutions that used UTAAM in the combination and prediction solutions.

Table 3. Mean magnitude of the differences between the Daily solutions with respect to C04 Earth Orientation Solutions for 2001.

Days in Future	X 0.001"	Y 0.001"	UT1-UTC ms	ψ 0.001"	ε 0.001"
1	.17	.11	.002	.14	.11
5	.85	.03	.031	.14	.11
10	2.15	.12	.025	.14	.12
20	5.42	.75	.356	.14	.12
40	12.2	3.25	1.36	.14	.12
90*	21.1	16.4	5.02		

* ψ and ε not predicted to 90 days into future in daily solutions.

Table 4. Standard Deviation of the differences between the Daily solutions with respect to C04 Earth Orientation Solutions for 2001.

Days in Future	X 0.001"	Y 0.001"	UT1-UTC ms	ψ 0.001"	ε 0.001"
1	.51	.47	.145	.59	.25
5	2.22	1.76	.732	.61	.26
10	3.99	2.93	1.88	.63	.27
20	6.86	5.21	4.21	.64	.28
40	11.1	10.6	5.45	.70	.29
90	18.9	21.2	10.47		

* ψ and ε not predicted to 90 days into future in daily solutions.

The predictions of ψ and ε are based solely on VLBI data. If no new data is available, a new prediction of these nutation angles cannot be determined. Therefore, the length of the prediction into the future for ψ and ε can and does vary in the daily solution files.

Predictions, of UT1-TAI up to 2010 January 1, are given in Table 5 below. They are derived using a prediction algorithm similar to that employed in the Bulletin A predictions of UT1-UTC. Up to twenty years of past observations of UT1-TAI are used. Estimates of the expected one-sigma error for each of the predicted values are also given. These are based on analyses of the past performance of the model with respect to the observations.

Table 5. Predicted values of UT1-TAI, 2002-2010. Note that TT-UT1 can be obtained from this table. Using the expression TT-UT1=32.186s – (UT1-TAI).

DATE	UT1-TAI (s)	Uncertainty (s)
2002 Jan 1	-32.115	.001
2002 Apr 1	-32.189	.001
2002 Jul 1	-32.229	.001
2002 Oct 1	-32.24	.01
2003 Jan 1	-32.30	.01
2003 Apr 1	-32.36	.02
2003 Jul 1	-32.57	.03
2003 Oct 1	-32.80	.04
2004 Jan 1	-33.02	.06
2004 Apr 1	-33.25	.08
2004 Jul 1	-33.4	.1
2004 Oct 1	-33.7	.2
2005 Jan 1	-33.9	.2
2005 Apr 1	-34.1	.3
2005 Jul 1	-34.4	.4
2005 Oct 1	-34.6	.4
2006 Jan 1	-34.8	.5
2006 Apr 1	-35.0	.6
2006 Jul 1	-35.3	.8
2006 Oct 1	-35.5	.9
2007 Jan 1	-36.	1.
2007 Apr 1	-36.	1.
2007 Jul 1	-36.	1.
2007 Oct 1	-36.	1.
2008 Jan 1	-37.	2.
2008 Apr 1	-37.	2.
2008 Jul 1	-37.	2.
2008 Oct 1	-37.	2.
2009 Jan 1	-37.	2.
2009 Apr 1	-37.	3.
2009 Jul 1	-38.	3.
2009 Oct 1	-38.	3.
2010 Jan 1	-38.	3.

Please contact the IERS Rapid Service/Prediction Centre for details on how to obtain these data. Further information on recent improvements to IERS Bulletin A and the significance for predictions of GPS orbits for real-time users is provided in the paper by Luzum et al. (2001).

Centre Activities in 2001

During 2001 several substantial changes have occurred which affect the performance of IERS Bulletin A. In December of 2000, it was determined that the contributions of the National Centers for Environmental Prediction (NCEP) model estimates of Atmospheric Angular Momentum (AAM) excitation of Length of Day (LOD) were actually degrading the near-term UT1-UTC predictions. Therefore, the contributions of AAM were removed from the Bulletin A solution and the usefulness of the NCEP model to the prediction of UT1-UTC was reevaluate. This reevaluation indicated the presence of quasi-periodic variability in the AAM-derived LOD that was not present in the UT1-UTC time series. It was determined that this variability could be reduced and that the resulting AAM-derived LOD time series could improve the centre's near-term UT1-UTC predictions (Johnson et al., 2002). Therefore, beginning with 14 August, the AAM-derived LOD time series was re-introduced into the combination of datasets used in the solution of IERS Bulletin A (Rapid Service and Predictions of EOP).

Beginning with the 1 May 2001 issue of IERS Bulletin A, we have adopted the system of our Annual Report submission. This involves changing the systematic corrections and weights of the contributing series. We have also removed the USNO VLBI reductions from the combination procedure. For recent data, the RMS differences in polar motion are less than 50 μas and in UT1-UTC are less than 5 μs.

Starting 22 May, the number of past data points used to estimate polar motion predictions was changed from 1100 days to 400 days. In testing the two prediction lengths since 1995, the new algorithm produced significantly better results for all prediction intervals. While the shorter time span makes separating the Chandler and annual oscillations more difficult, the advantage is that time-varying characteristics of the oscillations change less year-to-year than they do over the course of four years. This change has caused a larger-than-normal change in the polar motion prediction coefficients and in the long-term polar motion predictions.

Beginning 9 October, the IGS Final EOP file is being used. The new file is a concatenation of several originally inhomogeneous segments, all of which have been transformed to be consistent with the ITRF97 realization. The affect of this change on IERS Bulletin A polar motion values is generally less than about 0.1 mas. For the period since 51601.5 (27 Feb 2000), when the SINEX combination officially replaced the previous orbit combination series, the mean and RMS difference for Bulletin A polar motion are nearly zero and 0.036 mas, respectively, for each component. However, the differences are not entirely random. For the most recent period, the previous difference of about 0.1 mas between IERS Bulletins A and B for PM-y has been reduced almost to zero.

Availability of Rapid Service

The data available from the IERS Rapid Service/ Predictions Centre consists mainly of the data used in the IERS Bulletin A. This includes: x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from NEOS VLBI; x, y, UTC1-UTC $d\psi$, $d\varepsilon$, from IAA VLBI; x, y, UT1-UTC, $d\psi$, from GSFC VLBI; UT1-UTC from NEOS 1-day Intensives; UT1-UTC from SpbU 1-day Intensives; UT1-UTC from GSFC 1-day Intensives; x, y, UT1-UTC from GSFC 1-day Intensives; x, y, UT1-UTC from CSR LAGEOS 3-day SLR; x, y from Delft University of Technology 3-day SLR; x, y from Institute of Applied Astronomy 1-day SLR; x, y from the Russian Mission Control Centre 1-day SLR; UT0-UTC from University of Texas LLR; x, y, LOD from the International GPS Service; UT from USNO GPS; UT from NRCanada (EMR) GPS; x, y, UT1-UTC, $d\psi$, $d\varepsilon$, from the IERS Rapid Service/Predictions Centre; x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from the IERS Earth Orientation Centre; predictions of x, y, UT1-UTC, from the IERS Rapid Service/Predictions Centre.

In addition to this published information, other data sets are available. This includes: UT0-UTC from JPL LLR; UT0-UTC from CERGA LLR; UT0-UTC from JPL VLBI; latitude and UT0-UTC from Washington PZTs 1,3,7; latitude and UT0-UTC from Richmond PZTs 2,6; x and y from CSR LAGEOS 5-day SLR; x and y from Delft 5-day SLR; x, y, UT1-UTC, $d\psi$, and $d\varepsilon$ from IRIS VLBI.

The data described above are available from the Centre in a number of forms. You may request a semiweekly machine-readable version of the IERS Bulletin A containing the current ninety days worth of predictions via electronic mail form

<ser7@maia.usno.navy.mil> or <http://maia.usno.navy.mil/>.

Internet users can also direct an anonymous FTP to

<maia.usno.navy.mil>

and change to the ser7 directory where they can access the IERS Bulletin A or more complete databases.

World Wide Web access is available at

<http://maia.usno.navy.mil/>.

Centre Staff

For most of 2001, the Rapid Service/Prediction staff consisted of the following members.

Jim R. Ray	program manager
Brian Luzum	daily operations & software manager
Thomas Johnson	research, software maintenance and support
Meri-Sue Carter	assists in daily operations and support
Jerry Josties	assists in operations and support

In December of 2001, Brian Luzum resigned from USNO and the program. Currently, Thomas Johnson is managing the program.

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Thomas Johnson

3.5.3 Convention Centre

The Convention Centre is provided jointly by the U.S. Naval Observatory (USNO) and the Bureau International des Poids et Mesures (BIPM), who are working on the new edition of the IERS Conventions. The new edition has been slightly re-organized with respect to Conventions 1996, and numerous updates have been introduced. The work accomplished or in progress is the following:

Chapter 1 – General Definitions and Numerical Standards
The chapter has been updated for consistency of notation and concepts with other sections according to IAG and IAU working groups and expanded to provide definitions for concepts used throughout the document.

Chapter 2 – Conventional Celestial Reference System and Frame
The chapter has been updated to incorporate the effects of the IAU 2000 24th General Assembly

Chapter 3 – Conventional Dynamical Realization of ICRF
The chapter has been updated to be consistent with notation and concepts of other sections

Chapter 4 – Conventional Terrestrial Reference System
The chapter has been updated for ITRF2000.

Chapter 5 – Transformation Between the Celestial and Terrestrial Systems.
The chapter is being modified to be consistent with resolutions adopted at the 24th IAU General Assembly and the 2002 IERS Workshop.

Chapter 6 – Geopotential
The chapter has been updated to include the EGM96 conventional geopotential model and for the treatment of tides.

Chapter 7 – Site Displacement
The chapter has been updated to account for models used in IERS analysis centres and to ensure consistency with chapters 4 and 6.

Chapter 8 – Tidal Variations in the Earth's Rotation
The chapter has been updated to be consistent with resolutions adopted at the 24th IAU General Assembly

Chapter 9 – Tropospheric Model
The chapter has been updated.

Chapter 10 – General Relativistic Models for Time, Coordinates and Equations of Motion
The chapter has been updated for consistency of notation and concepts with other sections.

Chapter 11 – General Relativistic Models for Propagation
The chapter has been updated for consistency of notation and concepts with other sections.

Appendix – Resolutions of the 24th IAU General Assembly

New versions of chapters and accompanying software are posted on the web as they become available, see
<http://maia.usno.navy.mil/conv2000.html>.

Gerard Petit, Dennis D. McCarthy

3.5.4 ICRS Centre

Introduction

The IAU has charged the IERS with the responsibility of monitoring the International Celestial Reference System (ICRS) and maintaining its current realization, the International Celestial Reference Frame (ICRF), and links with other celestial reference frames. Starting in 2001, these activities are run jointly by the ICRS Centre (Observatoire de Paris and U.S. Naval Observatory) of the IERS and the International VLBI Service for geodesy and astrometry (IVS), in coordination with the IAU Working Group on the Reference System. The present report was jointly prepared by the Paris Observatory and U.S. Naval Observatory components of the ICRS Centre.

The International Celestial Reference System (ICRS) is materialized by coordinates of extragalactic radio sources derived from VLBI observations. The access to ICRS in radio wavelengths is given by the 667 extragalactic radio sources in ICRF-Ext.1 (IERS, 1999). This extension of the initial ICRF was constructed and issued as a part of the maintenance process of the conventional celestial system and its frame (Ma *et al*., 1997, 1998). While the set of the 212 defining sources and their respective coordinates remain unchanged with respect to the first realization of the frame, more precise coordinates for sources classified as “candidate“ and “other“ in ICRF are provided in ICRF-Ext.1; 59 “new“ sources that were not included in the initial ICRF increase the number of objects in the conventional frame.

Concerning the ICRS monitoring, the location of the ICRS origin of right ascensions relative to the dynamical equinox is monitored using Lunar Laser Ranging (LLR) solutions. The location of the ICRS pole relative to the Celestial Ephemeris Pole is monitored using VLBI-derived celestial frames and time series of the celestial pole offsets.

Various investigations concerning ICRF-Ext.1 are presented, based on the contributions from VLBI analysis centres: additional sources since the construction of ICRF-Ext.1, stability analyses based on time series of source coordinates, and comparisons of the ICRF with newly computed radio source catalogues.

The link of the ICRF to the Hipparcos frame which is the primary realization of the ICRF at optical wavelengths, as well as the link with other frames as 2MASS (infrared catalogue) is also one of the fundamental objectives of the ICRS Centre. The ICRS Centre organizes and updates a database which contains VLBI celestial frame realizations achieved during the last 15 years.

Different files provide information to characterize the objects involved (radio source nomenclature, physical characteristics of radio sources, astrometric behavior of a set of sources, radio source

structure). The database is available at URL
<http://hpiers.obspm.fr/icrs-pc>,
by anonymous ftp (<hpiers.obspm.fr/icrs-pc>), and on request to the ICRS Centre (<icrs-pc@hpopa.obspm.fr>).

In the following, we explain the contents of the various tasks which are devoted to the ICRS Centre, by explaining for each of them the studies which were developed in 2001.

Task 1: Maintenance and extension of the ICRF

The VLBI observing program, which is coordinated by the IVS permanently, brings in new observations of ICRF, and prospective ICRF sources. For sake of consistency, a permanent check of the coordinates of known sources is carried out, whereas ICRS coordinates of new sources are derived.

Moreover, comparisons have been done between the ICRF and celestial catalogues produced as a result of all the observations carried out for the year 2001 by different VLBI groups. Four individual original catalogues and one combined catalogue have been received and analysed, respectively from the GSFC (Goddard Space Flight Center), the BKGI (Bundesamt für Kartographie und Geodäsie, Leipzig, and Geodetic Institute of the University of Bonn), the IAA (Institute of Applied Astronomy of the Russian Academy of Sciences, St. Petersburg), the SHA (Shanghai Observatory of Chinese Academy of Sciences) in one part, and from GAOUA (Main Astronomical Observatory of the Ukranian Academy of Sciences) for the other part. We give the corresponding rotations between the ICRF and each of these catalogues according to the three rectangular axes as well as the slopes and the bias according to the equatorial coordinates.

Notice that in the BKGI, IAA and GSFC catalogues, 23, 8 and 13 new sources respectively were observed in 2001, which are not included in the ICRF. The first extension to the ICRF, ICRF-Ext. 1, was issued by the IERS in 1998 (see the 1998 IERS Annual Report). No revision of the ICRF has been decided during 2001.

Task 2: Investigation of future realizations of the ICRS

Involvement in the celestial reference frame VLBI program continued by PC personnel in 2001, significantly increasing the number of observations of ICRF quasars in the southern celestial hemisphere and continuing an extensive observing program in the northern hemisphere. These observations may eventually result in the issuing of a second extension to the ICRF.

The northern hemisphere VLBI observing program includes a series of experiments involving the 10 VLBI stations of the U.S. National Radio Astronomy Observatory (NRAO) Very Long Baseline Array (VLBA) (see Task 3 narrative for an description of the program). Preliminary analysis of this series of experiments indicated these data had significant systematic errors of unknown origin. Additional analysis of these data by PC personnel, performed in 2001, showed that the initial concerns were unfounded, and that these data should be incorporated into the general astrometric and geodetic VLBI database.

In the coming decades, there will be significant advances in the area of space-based optical astrometry. Proposed and scheduled missions such as the National Aeronautics and Space Administration's (NASA) Space Interferometry Mission (SIM) and the European Space Agency's GAIA mission will achieve positional accuracies well beyond that presently obtained by any ground-based radio interferometric measurements. During 2001, PC personnel were involved in the Full-sky Astrometric Mapping Explorer (FAME) mission; a NASA sponsored astrometric space mission to measure the position, parallax and proper motions of 40 million stars between 5th and 15th magnitude. During 2001 the FAME project was in Phase B: the preliminary design phase. FAME's Phase B culminated in several reviews held in October, November and December of 2001, including a Preliminary Design Review, a Confirmation Assessment Review and a Confirmation Readiness Review. At the end of 2001 the FAME project was awaiting NASA Headquarters' decision on whether FAME would proceed in to Phase C (detailed design phase).

Task 3: Monitor Source Structure (2001)

Observations of International Celestial Reference Frame (ICRF) sources using the Very Long Baseline Array (VLBA), together with several geodetic antennas, continued. These observations constitute a joint program between the U.S. Naval Observatory (USNO), Goddard Space Flight Center (GSFC) and the National Radio Astronomy Observatory (NRAO) for maintenance of the celestial and terrestrial reference frames.

This program has proven highly successful, providing source images with up to twice the resolution of VLBA only observations, Earth Orientation Parameter (EOP) estimates with precision exceeding that of regular EOP observations, repeated high quality source and station position estimates, and precise positions for several phase reference sources requested by VLBA users. Results from previous observing sessions are providing some of the best astrometric/geodetic data ever obtained and are providing the basis for evaluation of the long term stability of the ICRF.

The VLBA observations taken under this program provide data suitable for imaging of the intrinsic structure of the extragalactic radio sources which make up the ICRF. Images are made at the USNO and are made available for use by anyone from the USNO Radio Reference Frame Image Database (RRFID). The RRFID can be accessed on the World Wide Web at <http://www.usno.navy.mil/RRFID/>. During the reporting period (2001), a total of

330 new images of 165 sources were added to the RRFID.

Images produced at USNO are analysed by the USNO for variability and are monitored for structural changes. Analysis of previous observations has provided valuable information on the intrinsic structure and variability of the observed sources, allowing us to characterize and classify sources based on their observed structure (Fey et al., 2001) and structural variability (Piner et al., 2002).

RRFID images are also used by various other institutions to assess the impact of source structure on astrometric position determination. The USNO and Bordeaux groups analyze the images produced by the USNO to estimate the effect of source structure on the measurement of group delay and produce a source 'Structure Index' which is a measure of the astrometric quality of a source, based on its intrinsic structure (see Fey and Charlot, 2000, and references therein). These studies have revealed a correlation between the observed radio structure and source position accuracy and stability. The assumption that such source structure errors can be minimized or removed through the application of source structure corrections has been investigated by Sovers et al. (2002). Results of this study suggest that source structure contributes significantly, but the primary contribution to astrometric error comes from the troposphere.

Task 4: Monitor coordinates to assess astrometric quality

Studies of the time stability of radio source coordinates were carried out in 2001, in the continuity of previous ones (Gontier et al., 2001). Time series of source coordinates were taken from USNO data (A. Fey, 2002). A total of about 3000 sessions are considered, involving about 700 sources and 3 million total observations. The work consisted of several steps: transforming the time series for each source into a series of differences to its mean coordinates over the period 1983.5–2002.0; transforming the difference time series of the 273 most regularly observed sources into a series of normal points at one-year intervals; analysing the time behaviour of the source coordinates, to derive a stability criteria. Another fundamental test consisted in evaluating the impact of source selection on the no-net-rotation condition of the CRF and on the determination of precession-nutation coefficients.

By selecting a sub-catalogue of 162 sources among the initial set of 273 ones, with the help of a stability criteria (Feissel, 2002) it can be shown that the year-to-year stability of the given catalogue, indicated by the amplitude of the related rotations around the three perpendicular ICRS axes, is noticeably better than for the defining sources of the ICRF catalogue. Moreover the quality of determination of the precession correction and of the obliquity rate are improved by the choice of a limiting number of sources above.

Task 5: Maintenance of the link to Hipparcos

During the report period (2001) several observational programs were ongoing. These fall into 3 categories: the densification of the reference frame at optical wavelengths, extension of the Hipparcos frame to infrared (IR) wavelengths, and the critical check on the radio to optical reference frame link itself.

The major program for the densification of the optical reference frame is the UCAC project (USNO CCD Astrograph Catalog). This all-sky survey will give 20 mas positions for stars in the 10 to 14 mag range, with a limiting magnitude of about R=16. The first release (UCAC1) was published in March 2000, containing positions and proper motions of 27 million stars on the Hipparcos Catalogue Reference System (HCRS). In September/October 2001, the astrograph was relocated from CTIO (Chile) to Flagstaff, AZ. By the end of 2001, observations over 76% of the sky were completed.

Other densification projects include the Carlsberg Meridian Circle program (Denmark, UK, Spain) of scanning the –3 to +30 degree zone, as well as a similar project from Bordeaux Observatory for the +11 to +18 degree zone. The Sloan Digital Sky Survey (SDSS) continued its deep 5-band photometric survey in areas around the galactic north pole. Astrometry is tied to the HCRS via Tycho-2 and UCAC positions.

The major program to extend the Hipparcos frame into wavelengths other than optical or radio is the 2-micron All Sky Survey (2MASS) project. IR photometry (J,H,K) has been obtained with 2 identical telescopes (north, south) for about 400 million point sources. The astrometry is on the HCRS and the average error per catalogue position coordinate is expected to be around 100 mas with much smaller systematic (zonal and magnitude dependent) errors.

Task 6: Linking the ICRF to frames at various wavelengths

The linking of the ICRF to frames at other catalogues means two different objectives:

A first objective is the compilation of the information extracted from various observational programs, concerning the extragalactic objects belonging to the ICRF catalogue. Activities of the ICRS-PC in 2001 in this topic were devoted to the cross-identification between the extragalactic sources of the ICRF and the quasars catalogues whose the list can be obtained from the CDS (Centre for Stellar Database, France). More precisely, efforts were made in adding supplementary information (redshifts, optical magnitudes etc...) for the ICRF objects, whatever their status (defining sources, candidates sources, other sources)

A second objective is the geometrical link between the ICRF catalogue and other catalogues at other wavelengths. This geometrical link can be obtained by identifying common objects (to the ICRF and to the catalogue to be linked). In this field, a comprehensive extragalactic link program is part of the UCAC project. The goal is to eventually provide a link between the ICRS and the UCAC independent of HCRS (using block adjustment procedures) and then quasi externally assess the HCRS-ICRS link. Optical positions of about 120 ICRF sources were obtained in 3 observing runs at CTIO and KPNO during 2001, supplemented with some observations from LNA (Brazil) of optically faint targets.

Task 7: Maintenance of the link to the solar system dynamical reference frame using millisecond pulsar analysis

The idea of associating pulsar timing technique with differential VLBI astrometry should provide high quality information about the position and motion of the equator, the ecliptic, the equinox of the ICRS. Although no specific project in the association above was set up in 2001, pulsar timing experiments were conducted on a regularly basis at Nançay observatory (France). Observations of pulsars with a new instrument named NBPP (Naval research Lab, Washington) have been carried out with success.

Task 8: Maintenance of the link to the solar system dynamical reference frame using Lunar Laser Ranging (LLR) analysis

The dynamical reference frame can be materialized preferentially by the dynamical ecliptic of the date or at a given epoch. The combination of VLBI data, with LLR data enables the determination, with high accuracy, of the position of the inertial dynamical ecliptic at a given epoch with respect to the ICRS. One of the fundamental parameters is the mean obliquity of the Earth, together with the position of the mean equinox, at epoch J2000.0. The position of the dynamical equinox is related to the lunar orbit through ephemerides (ELP2000, DE405 etc...), whereas the position of the mean equator at J2000.0 is implicitly given by its orientation with respect to the instantaneous equator of the date by means of the precession-nutation matrix.

Efforts were made during 2001 by the team in charge of the LLR observations at Paris Observatory (see Chapront, M., Chapront-Touzé, M., Fancou, 2002) to define the ICRS equator and origin of right ascension from the rectangular coordinates of the LLR stations in the terrestrial reference frame (through the ICRF) and the transformation from terrestrial coordinates to the J2000.0 equatorial coordinates. This last transformation has been realized according to the lunar solution S2001 (ICRS) which results from weighed fits of the semi-analytical theory ELP2000-96 of the orbital motion of the Moon to the LLR observations provided between 1970 and 2001. The precession-nutation matrix is computed via the conventional set of values recommended by IERS in particular the nutation corrections of the series EOP(C04) produced by the Earth Orientation Centre.

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Sovers O.J., Charlot P., Fey A.L., Gordon D., 2002, IVS2002 General Meeting Proceedings, 243, N. Vandenbergh and K.D. Baver (eds.), http://ivscc.gsfc.nasa.gov/publications/gm2002/sovers/

Jean Souchay, Ralph A. Gaume

3.5.5 ITRS Centre

Contribution to the IERS Conventions

A new and complete chapter on the ITRS is now available, describing the mathematical theoretical definition and realization of the ITRS. It includes a full description of the ITRF versions, emphasizing on the ITRF2000, the Current Reference Realization of the ITRS.

ITRF Working Groups Activities

- IERS Working Group on the ITRF Datum: this group, chaired by Kristine Larson, continues his activities under a discussion forum between the members, essentially on the ITRF datum definition, in terms of rotational datum (sub-group chaired by Geoff Blewitt) and Geocentre Motion (sub-group chaired by Mike Watkins). A dedicated web site is available: <http://phys-geophys.colorado.edu/~kristine/ITRF/ITRF.html>. A special AGU Fall 2001 session was devoted to the TRF issues, convened by K. Larson and Z. Altamimi.

- Working Group on Local Ties: this group is created under the IAG/CSTG, chaired by Jim Long, taking over the activities of John Bosworth. Progress is made on documentation of local survey specification as well as on new surveys on some collocation sites.

Relation With the IGS

The ITRS Centre contributes to specifications for ITRF densification, initiated by the IGS for its part (regional solutions of weekly permanent GPS station positions). Work is still in progress for evaluation/comparison of the different proposed densification approaches.

Maintenance of the IERS Network

This activity includes update of the IERS network database in terms of new sites and stations, assignment of DOMES numbers, local ties, availability of IERS network information and ITRF products on the web and ftp server, as well as assisting the ITRF users for a proper use of ITRF products. Moreover, a new ITRS web site is developed and it is under its validation phase. This new web site will provide site information, station positions (at any epoch) and velocities in any ITRF version in SINEX or/and table list.

For more information, see also the report of the ITRS Combination Centre at IGN (section 3.6.1.2) and the report of the Combination Research Centre at IGN (section 3.6.2.9).

Zuheir Altamimi, Claude Boucher,
Patrick Sillard, Martine Feissel

3.6.6 Global Geophysical Fluids Center (GGFC)

Mass transports in the atmosphere-hydrosphere-solid Earth-core system, or the “global geophysical fluids”, will cause observable geodynamic effects on a broad time scale. The Global Geophysical Fluids Center (GGFC) and its Special Bureaus (SBs) have the responsibility of supporting, facilitating, and providing services to the worldwide research community in areas related to the variations in Earth rotation, gravitational field and geocenter that are caused by mass transport in the geophysical fluids and the induced loading effects.

The GGFC was established by the International Earth Rotation Service (IERS) on IERS’s 10th anniversary day January 1, 1998, in an effort to expand IERS’s services to the scientific community, which had already included those of the Sub-Bureau for Atmospheric Angular Momentum since 1989. Under the GGFC, seven SBs were established initially (SB for Atmosphere, Oceans, Hydrology, Tides, Mantle, Core, and Gravity/Geocenter). In 2002 an eighth SB, the SB for Loading was added after a formal proposal-selection process administered by the IERS Directing Board. Additional, but slight, changes in personnel in the SB structure were also implemented in 2002 (see Appendix 2).

Under GGFC/SBs, angular momenta and the related torques, gravitational coefficients, geocenter shift, and surface loading deformation fields will be computed for all geophysical fluids based on global observational data, and/or products from state-of-the-art models some of which assimilate such data. The computed quantities, algorithm and data formats will be standardized. The data products are, and additional ones will be, archived and made available to the scientific research community.

The web sites given in Appendix 3 contain detailed information of GGFC and the SBs, including description and availability of archived data, useful graphics, members/associates list, call for participation, planned activities, and bibliography, etc. In particular, the following article defining GGFC, published in 2000, is posted on the GGFC website, courtesy of the American Geophysical Union: Chao, B. F., V. Dehant, R. S. Gross, R. D. Ray, D. A. Salstein, M. M. Watkins, and C. R. Wilson, Space geodesy monitors mass transports in global geophysical fluids, *EOS, Trans. Amer. Geophys. Union, 81*, 247-250, May 30, 2000.

The two most recent GGFC meetings were conducted during the 2001 and 2002 European Geophysical Society General Assembly; on March 29, 2001, and April 24, 2002, respectively, in Nice, France. Both were open discussion meetings attended by around 30 interested scientists. In addition, two GGFC papers were presented at international conferences: (1) Ocean Hemisphere

Project Symposium, Japan 2001 (by B. Chao); and (2) EGS2002 Assembly, Nice (newly-established SB for Loading presentation by H.-P. Plag).

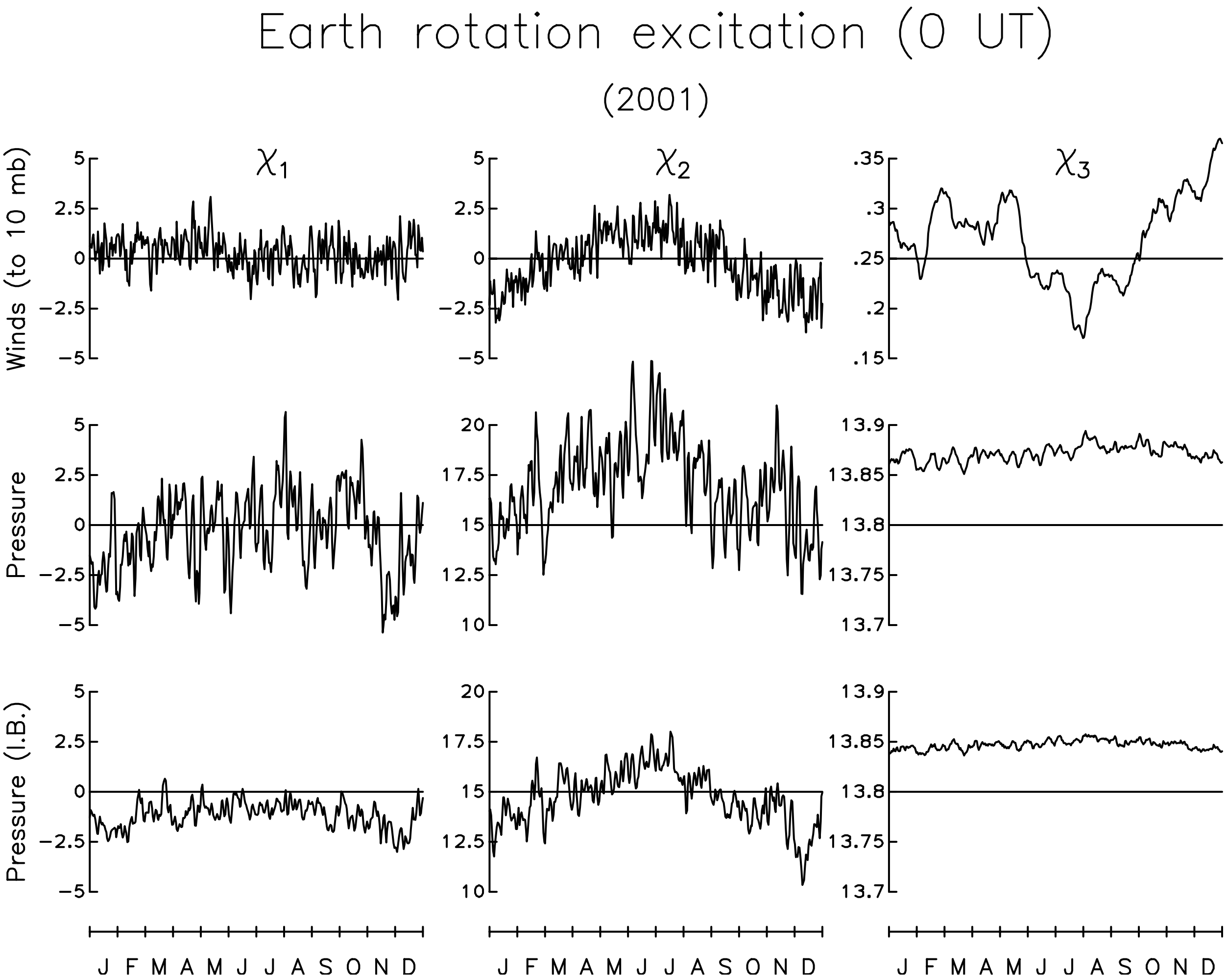
Detail reports from each SB follow.

Benjamin F. Chao

3.5.6.1 Special Bureau for the Atmosphere

In conjunction with the U.S. National Oceanic and Atmospheric Administration (NOAA), the SB Atmosphere has produced and made available atmospheric parameters from 4 different operational meteorological centres related to the needs of the IERS. We have also produced data from atmospheric reanalyses, spanning back to 1948. SBAtmosphere organized a system to operate in two modes. In the first, it supplies the data in near real time through the service at NOAA, including both analyses and forecasts. In the second mode, it updates monthly archives of the data on the FTP server at Atmospheric and Environmental Research, Inc. (AER).

Figure 1: Atmospheric excitation of polar motion (equatorial components X1 and X2) and Earth rotation (axial component X3), given in nondimensional units, based on the reanalyses of the U.S. National Centers for Environmental Prediction-National Center for Atmospheric Research for the year 2001, at 00 UTC. Separate values are given for the effect of wind, pressure, and pressure as modified by the inverted barometer.



The principal data prepared relate to atmospheric excitations of the Earth rotation vector, as forced by changes in the winds and surface pressure of the atmosphere, known respectively also as the motion and mass terms of the atmospheric angular momentum (AAM). For the axial component, related to length of day, the stronger term is the motion one, and for the equatorial term, related to polar motion, the mass term dominates. An "inverted barometer" correction is produced to the mass terms, designed to model an equilibrium condition of the oceans in which the oceans are depressed in response to a higher atmospheric pressure and rise in response to a lower one. The atmospheric excitations for Earth rotation/polar motion for the year 2001, based on the NCEP-NCAR reanalysis are given in Fig. 1. Though available 4 times daily, these are given here once daily, at 0 UT, for clarity and to eliminate high amplitude subdaily signals.

SBAtmosphere also computes the AAM terms, locally, in a number of equal-area sectors distributed around the globe, as well as globally. In addition, SBAtmosphere computes the mean atmospheric surface pressure over the globe, and various spherical harmonics, which are related to the Stokes coefficients of the Earth gravity field. Users log in to our ftp sites to obtain the desired information. Having kept track of our data usage during a recent short period, for example, the data were accessed by 12 different IP (Internet Protocol) addresses during two recent months of 2001.

Two reports have been prepared:

Salstein, D. A., O. de Viron, M. Yseboodt, and V. Dehant, 2001: High-frequency geophysical fluid modeling necessary to understand Earth rotation variability, EOS. AGU Publication, 82(21) pp. 237-238.

Salstein, D.A., and A. J. Miller, 2001: The special bureau for the atmosphere of the International Earth Rotation Service, submitted, IERS Technical Note, ed. B.F. Chao, International Earth Rotation Service.

David A. Salstein

3.5.6.2 Special Bureau for the Oceans

The oceans have a major impact on global geophysical processes of the Earth. Nontidal changes in oceanic currents and ocean-bottom pressure have been shown to be a major source of polar motion excitation and also measurably change the length of the day. The changing mass distribution of the oceans causes the Earth's gravitational field to change and causes the center-of-mass of the oceans to change which in turn causes the center-of-mass of the solid Earth to change. The changing mass distribution of the oceans also changes the load on the oceanic crust, thereby affecting both the vertical and horizontal position of observing stations located near the oceans. As part of the IERS Global Geophysical Fluids Center, the Special Bureau for the Oceans (SBO) is responsible for collecting, calculating, analyzing, archiving, and distributing data relating to nontidal changes in oceanic processes affecting the Earth's rotation, deformation, gravitational field, and geocenter. The oceanic products available through the IERS SBO web site at <http://euler.jpl.nasa.gov/sbo> are produced primarily by general circulation models of the oceans that are operated by participating modeling groups and include oceanic angular momentum, center-of-mass, and bottom pressure. A subroutine to compute these oceanic products from the output of general circulation models can also be downloaded from the IERS SBO web site along with a bibliography of related articles.

During the past year, new contacts with ocean modeling groups were initiated, the bibliography of related articles was updated, and additional data sets were acquired. The data sets currently available through the IERS SBO web site are: (1) two different oceanic angular momentum series, one spanning 1985-1996 at 5 day intervals and the other spanning 1988-1997 at 3 day intervals, (2) two different oceanic center-of-mass series, both spanning 1992-1994 at 3 day intervals but produced by different ocean models, and (3) two different ocean-bottom pressure data sets, both given at 12-hour intervals but one spanning 1993 to the present produced by a data-assimilating ocean model and the other spanning 1980 to the present produced by an ocean model that does not assimilate any data.

Richard Gross

3.5.6.3 Special Bureau for Tides

The Special Bureau for Tides collects datasets related to the effects of tides on Earth rotation and geocenter motions. It also collects tables of spherical harmonic coefficients for both oceanic and atmospheric tides. The data archive that the Bureau maintains has slowly grown as individual tidal investigators contribute their modeling results. Although there are many new ocean tide models still appearing in the oceanographic community as a result of the Topex/Poseidon altimeter mission, not all these models are appropriate for the Bureau because not all investigators are able to provide tidal currents; currents are as important as elevations for studying tidal variations in Earth rotation. There is currently a lack of data related to atmospheric tides, although in 2001 the Bureau added spherical harmonic coefficients for a new model of the S2 air tide. Work is also planned to collect similar older models.

The web site of the Special Bureau <bowie.gsfc.nasa.gov/ggfc/tides> continues to see a growing number of “hits” per day. By far the most popular destination is a short tutorial that explains tidal variations in Earth rotation; apparently this high activity is caused by a number of other tidal sites linking to this page.

A major area of planned improvement over the next year is the addition of data related to long-period tides and atmospheric tides. The latter are especially difficult because most meterological centers distribute products with a 6-hour sampling, which is the Nyquist period of the S2 tide. Temporal interpolation procedures are being investigated to partially overcome this difficulty. Such work has already revealed phase lag errors in the tides from the NCEP and ECMWF centers.

Richard D. Ray

3.5.6.4 Special Bureau for Hydrology

The goal of the Special Bureau for Hydrology is to provide internet access to water storage datasets of surface load variations for all land areas of the world. We have made significant progress in posting on the web site both the gridded water load variations from several models, and the earth rotation excitation time series calculated by summation over the land surface grid.

At the moment there are two principal numerical models results that are available. The NCEP (National Center for Environmental Prediction) Reanalysis model represents a fixed data-assimilating global numerical model, designed mainly for atmospheric studies. It has now been run for a period exceeding 50 years, starting in 1948. The hydrologic part of this model is primitive, and reflects a combination of an imposed (non data-assimilating) hydrologic cycle, and some interaction with the atmosphere and climate. We regard the hydrologic time series and load variations as representative of the real Earth variations, but probably not accurate in detail, especially in interannual variability. There are evident flaws in the hydrologic values for Antarctica and Greenland, and we interpret these in part to be estimates of a combination of sea ice and land ice. Sea ice is not significant geodetically, because it is part of the oceans, but its appearance in the gridded files means that we must exclude Antarctica and Greenland from the calculations. We expect hydrology to become more important in causing earth rotation variations at longer periods, so this is probably a serious flaw. Nevertheless, the NCEP results are valuable for their global coverage and long duration. The web site includes daily NCEP water storage in Gaussian gridded form (1979–2001), monthly water storage in 1 x 1 degree gridded format, and daily excitations for polar motion and length of day for 1948–2001.

The ECMWF model (European Center for Medium Range Weather Forecasting) has a data-assimilating reanalysis model, similar to NCEP, also with a surface hydrologic cycle. We find that it appears more realistic than NCEP, showing greater interannual variability. The web site includes gridded values (2.5 degrees) at daily intervals for the period 1979–1993 of the water storage load changes.

At the moment there is no test on a global scale of the accuracy of either NCEP or ECMWF results. The hydrologic load variations are derived from the atmospheric model, and lack primary data (such as river discharge and actual precipitation) to constrain their results. We await the development of more sophisticated land surface models which can assimilate such data to provide better estimates of the hydrologic load variations, and related geodetic predictions.

Clark R. Wilson

3.5.6.5 Special Bureau for the Mantle

The Special Bureau for the Mantle has posted three sets of data:

(1) The co-seismic effects on various geodynamic parameters, including low-degree gravitational Stokes coefficients, Earth rotation parameters (length-of-day and polar motion excitation), and Earth's moments of inertia changes. They are shown as cumulative effects for 19,050 earthquakes spanning Jan 1977 through May 2002. The computation is based on Chao & Gross, 1987 (Chao, B. F. and Gross, R. S., Changes in the Earth's rotation and low-degree gravitational field induced by earthquakes, *Geophys. J. Roy. Astron. Soc.*, 91, 569-596, 1987) using the centroid-moment tensor solutions of all major earthquakes larger than magnitude 5 as published in the Harvard CMT catalogue.

(2) Post glacial rebound modeling data from Eric Ivins (JPL). This set of data consists of graphics and spherical harmonic geopotential rates complete through degree 12 for each of three different cases. The geopotential rates are provided as a function of the lower mantle viscosity ranging from $1x10^{21}$ to $1x10^{23}$ Pa sec. The first case uses ICE3G and a standard (Tushingham and Peltier, 1991) earth model. The second case has an upper mantle viscosity of 3.2×10^{20} Pa sec (Johnston and Lambeck, 1999) and lithosphere thickness = 80 km. The third case has a fixed deepest mantle (CMB to 650 km above) viscosity at eta = 7×10^{22} Pa sec, variable mantle viscosity from 650 km above the CMB to the 670 km seismic siscontinuity, an upper mantle viscosity of 5×10^{20} Pa sec and a lithospheric thickness of 100 km.

(3) Post glacial rebound modeling data from Prof. Richard Peltier (University of Toronto). This set consists primarily of the graphics from chapter 4 in the recent book “Sea Level rise: History and Consequences” (ed. B. Douglas, M. Kearney, and S. Leatherman, Academic Press, San Diego, 2001).

Benjamin F. Chao

3.5.6.6 Special Bureau for the Core

Introduction

Our activities are mainly related to the scientific developments and results concerning the angular momentum exchange between the core and the mantle and the physical mechanisms (torques) at the Core-Mantle Boundary (CMB) and at the Inner Core Boundary (ICB). This angular momentum exchange induces variations in all three components of Earth rotation. Because there are no direct observations of the core flow that could lead to well-constrained models as do exist for the ocean and atmosphere, only calculations of core angular momentum (CAM) can be obtained from core flows derived from variations in the magnetic field observed at the Earth surface. Further, these flows depend on poorly constrained additional assumptions to resolve formal non-uniqueness in the solution. On our web site <www.astro.oma.be/SBC/main.html>, we have collected data of core angular momentum. We have also given explanations related to the different assumptions that may be used for the core angular momentum computations. In addition, we included a review of the candidate coupling mechanisms that are currently under investigation for explaining this angular momentum exchange (possible torques at the CMB).

Data of Core angular momentum computations

We have put 9 series of CAM on our web site, with their physical assumptions and the references to be mentioned.

The assumptions used are based on our understanding of the physical process involved. First of all, based on order of magnitude evaluation at decade time scale, only the induction term is retained in the magnetic induction equation, equivalent to the frozen-flux approximation (the changes in the magnetic field lines follow the flow line changes). Secondly, dealing with more unknowns than equations, it is necessary to further consider an additional constraint. In the literature, one finds four additional constraints (1) toroidal field flow, (2) piecewise steady flow, (3) flow steady in a drifting frame, (4) tangentially geostrophic flow. The series put on the web are mainly related to the last hypothesis.

Further, these additional assumptions are poorly constrained. Consequently, the associated calculated changes of the Earth's angular momentum are quite uncertain. Still, the Length-Of-Day (LOD) changes calculated from these core flows agree remarkably well with the observed LOD changes.

The list of these CAM series is:

- Jackson's three different core angular momentum (CAM) based on the torsional oscillations using the hypothesis of fully time-dependent geostrophic flow and the surface magnetic field UFM1 of Bloxham and Jackson [1992, J. Geophys. Res. 97,

19537–19563] (for three different smoothings) [Jackson, 1997, PEPI 103, 293–311]
- Petrov's three different core angular momentum (CAM) based on the torsional oscillations using (a) the IGMF surface magnetic field and the geostrophic flow approximation, (b) the surface magnetic field and the quasi-steady flow approximation, and (c) the LOD observation, the surface magnetic field and the geostrophic flow approximation [Petrov and Dehant, not published];
- Jault's core angular momentum (CAM) based on the torsional oscillations using the tangential geostrophic flow and the surface magnetic field [Jault, Gire, and Le Mouël, 1988, Nature 333, 353–356];
- Pais' core angular momentum (CAM) based on the torsional oscillations using the tangential geostrophic flow and the surface magnetic field UFM1 of Bloxham and Jackson [1992, J. Geophys. Res., 97, 19537–19563] [Pais and Hulot, 2000, PEPI 118, 291–316];
- Boggs' core angular momentum (CAM) based on the torsional oscillations using the tangential geostrophic flow and the surface magnetic field UFM1 of Bloxham and Jackson [1992, J. Geophys. Res. 97, 19537–19563] [Hide, Boggs, and Dickey, 2000, Geophys. J. Int. 143, 777–786].

Bibliography

Additionally, we have built a bibliography of material relevant to the core that presently contains more than thousand references.

Book on "Earth's Core: Dynamics, Structure, Rotation"

Following an Union Session at the end of 2000 at the American Geophysical Union that we had organised, we have decided to edit a volume. The idea of the session was to bring together specialists of the core from different disciplines: seismology, geochemistry, geomagnetism, geodynamo and geodesy (Earth rotation). The book has the same philosophy and will be published at the end of 2002. The title of the book is "Earth's Core: Dynamics, Structure, Rotation", and the editors are V. Dehant, K. Creager, S. Karato, and S. Zatman. The book is dedicated to Stephen Zatman who died in an accident in July 2002. Stephen did a lot of research in the frame of LOD variations and the Earth core.

Change of Chair

Following the proposition of the present Chair of the SB for the Core, V. Dehant, and as approved by the IERS Directing Board, V. Dehant will be replaced for the next term (starting in July 2002) by her colleague Tim Van Hoolst.

Personal

Dehant, Veronique[1] (Chair)
and by alphabetic order:
Cardin, Philippe[2]
Chulliat, Arnaud[3]
Defraigne, Pascale[1]
de Viron, Olivier[1]
Dormy, Emmanuel[3]
Greff-Lefftz, Marianne[3]
Hinderer, Jacques[4]
Holme, Richard[5]
Hulot, Gauthier[3]
Jackson, Andrew[6]
Jault, Dominique[2]
Kuang, Weijia[7]
Legros, Hilaire[4]
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Veronique Dehant, Philippe Cardin, Arnaud Chulliat, Pascale Defraigne, Olivier de Viron, Emmanuel Dormy, Marianne Greff-Lefftz, Jacques Hinderer, Richard Holme, Gauthier Hulot, Andrew Jackson, Dominique Jault, Weijia Kuang, Hilaire Legros, Jean-Louis Le Mouel, Jerome Noir, Alexandra Pais, Tim Van Hoolst

3.5.6.7 Special Bureau for Gravity/Geocenter

Gravity

During 2001, most of the attention of the Special Bureau for Gravity/Geocenter (SBGG) staff was dedicated to preparation for the GRACE mission data analysis, archiving, and documentation. Recall that the SBGG website will serve as a portal for access to the GRACE Level-1 data and Level-2 gravity field products archived at the Physical Oceanography Distributed Active Archive Center and at the GeoForschungsZentrum Potsdam. The SBGG will provide not only links to these archives, but provide a forum for understanding the formats and standards of the data products, provide access to gravity solutions from other satellites including CHAMP and the SLR satellites, and links to access the geophysical data needed to interpret these changes. SBGG staff have contributed significantly to the preparation of GRACE Product Specification Document and the User Guide, which will be made publicly available in early 2003.

Geocenter

Several new data sets were added, including the latest IGS GPS results. Additional SLR and DORIS data sets were solicited and will be included in the next upgrade.

Web site

A major redesign and upgrade of the SBGG web site began in October 2002, to be completed by the end of 2002.

Michael M. Watkins

3.6 Combination Centres
3.6.1 ITRS Combination Centres
3.6.1.1 Deutsches Geodätisches Forschungsinstitut

Background and overview

Within the new IERS structure IGN and DGFI serve as ITRS Combination Centres (ITRS CC). The main task of the ITRS CC is the combination of space technique solutions provided by individual Analysis Centres and/or Technique Centres (e.g. IGS, ILRS, IVS, IDS) to derive the ITRF products (positions and velocities of the IERS network stations). The current space techniques contributing to the ITRF are VLBI, SLR/LLR, GPS and DORIS. The ITRS CC at DGFI works in close cooperation with the joint IERS Combination Research Centre at FGS (DGFI, FESG, GIUB). This ensures that the state of the art combination strategies, algorithms, software packages, etc. will be applied for the generation of our ITRS products. In this report the main components of the ITRS CC at DGFI are outlined and the main activities of the ITRS CC during the year 2001 are summarized. Finally this report contains recommendations for future ITRS realizations, as well as some remarks related to the definition of the IERS network and the specification of the ITRS products, which should be considered as a stimulation for discussions within the IERS. For more information we refer to our DGFI web page
<http://www.dgfi.badw.de/dgfi/IERS>.

Main components

The main components of the ITRS CC are:

- A **Data Management and Information System** to organize and provide all relevant ITRF data and products (e.g. station informations, local ties, ITRF input solutions, ITRF products)

- The **Data Analysis for ITRS Realization** comprising of:
  - Validation of submitted input data (solutions)
  - Generation of unconstrained normal equations for each individual solution
  - Combination of individual normal equations with DGFI Software DOGS-CS,
    Strategy:
    (1) Combination (comparison) of solutions of each technique
    (2) Combination (comparison) of techniques combined solutions
    (3) Iteration and final combined adjustment (weighting, datum definition, etc.)

- The **ITRF Quality Control** and external comparison with independently generated ITRF solutions being of major importance to ensure ITRF products with highest possible accuracy and reliability.

Combined Solution: ITRF2000_DGFI.P

DGFI has computed a first ITRS realization based on individual solutions, which were used by IGN for the computation of the official ITRF2000 (see Table 1). Note that this combined solution ITRF2000_DGFI.P is a preliminary version. Currently we are going to compute a refined combined solution. In particular we will try to include more individual solutions. Further detailed investigations will be related to local ties, relative weighting and the definition of the kinematic datum. Below the main processing steps are summarized.

1. **Validation**: We analyzed all ITRF2000 input solutions with regard to SINEX format compatibility, constraints, etc. We found that in some of the submitted solutions the SINEX format was not correctly and/or not completely adopted. Furthermore we checked the declarations of contraints applied to the submitted solutions and found remarkable contradictions (see Table 1 for more details).

2. **Generation of unconstrained normal equations**: Based on the results of the first step, we included 3 VLBI solutions (GIUB, GSFC, SHA), and 5 SLR solutions (CGS, CRL, CSR, DGFI, JCET). In case of GPS, we used the combined IGS solution instead of individual ones, because all individual GPS solutions are also contributing to the combined IGS solution.

3. **Combination:** We combined the unconstrained normal equations with the DGFI program DOGS-CS. In a first step we combined and analysed the individual solutions of the same technique, identified outliers and estimated relative weighting factors. Then we combined these intra-technique solutions (normal equtions) to derive the final combined (inter-technique) solution. These two combination steps were performed iteratively with regard to detection of outliers, weighting, etc.

4. **Datum definition**: The geodetic datum was defined similar to the official ITRF2000. The origin (translations and their rates) was defined by the weighted average of all contributing SLR solutions. For the definition of the scale and its rate we used all VLBI and all SLR solutions. The orientation and its rate was realized through a no net rotation condition with respect to ITRF2000 station positions and velocities for a subset of 40 sites.

Table 1 summarizes information on the individual solutions that contributed to the combined solution (ITRF2000_DGFI.P). Stations with a data time span of less than one year (except at co-location sites) were eliminated, because for these stations the accuracies for position and velocity are not satisfying. This criterium leads to the exclusion of 44 VLBI, 44 SLR and 21 GPS stations. Also the RMS differences of station positions and velocities between the individual solutions and the combined solution after applying 14 parameter similarity-transformations are shown.

Table 1: Summary of ITRF2000 input data (solutions) and the combined solution ITRF2000_DGFI.P. Note that in addition to the solutions shown in this table two multitechnique solutions and eight GPS-densification solutions were included in the official ITRF2000, which we did not include in our combination. For seven solutions we found contradictions with respect to the reported constraints (identified by a question mark); for some of these solutions the constraints were not documented in the SINEX files.

ITRF2000 Input Solutions					***Solutions in DGFI Combination***		
Technique	AC/TC	Data intervall	Constraints AC/TC	# Stations original	# Stations included	RMS Differences	
						Positions [mm]	Velocities [mm/a]
VLBI	GIUB	84-99	loose	51	50	3,8	0,6
	GSFC	79-99	loose	130	86	4,0	0,5
	SHA	79-99	loose	127	85	4,0	0,6
LLR	FGS	77-00	loose	3			
SLR	AUS	92-00	loose ?	55			
	CGS	84-99	loose	94	61	14,0	3,0
	CRL	90-00	loose	60	60	12,6	2,3
	CSR	76-00	loose	139	95	14,3	2,0
	DEOS	83-99	loose	91			
	DGFI	90-00	removable	43	39	13,5	2,2
	JCET	93-00	loose	48	41	7,2	1,8
GPS	CODE	93-00	minimum ?	160			
	GFZ	93-00	minimum ?	98			
	IGS	96-00	minimum	168	147	4,1	1,4
	JPL	91-99	minimum ?	112			
	NCL	95-99	minimum ?	90			
	NOAA	94-00	removable	165			
DORIS	GRGS	93-00	loose ?	66			
	IGN	92-00	minimum ?	80			

Comparison with official ITRF2000

We compared the ITRF2000_DGFI.P solution and the official ITRF2000 by means of a 14 parameter Helmert transformation. Below the major results are summarized:

Translations and rates:

T_x = 3.7 mm – 0.1 mm/yr
T_y = –2.8 mm + 0.5 mm/yr
T_z = 0.2 mm + 1.1 mm/yr

Scale and rate:

Sc = 0.1 ppb – 0.03 ppb/yr

With respect to the datum definition we have to consider that both ITRF realizations are based on the same SLR and VLBI solutions for defining the origin and the scale. Thus the comparison between both ITRF realizations can not be considered as completely independent quality control. As expected, the differences are small; they are below 4 mm for the translations and 1 mm/yr for the rates. The scale differs by only 0.1 ppb with a rate difference of 0.03 ppb/yr. The RMS residuals for positions are about 2 cm for SLR, and less than 1 cm for VLBI and GPS (see Table 2). The site velocities between both ITRF realizations show in general a good agreement (see Figure 1). The discrepancies are (in average) of the order of 1–3 mm/yr for all space-techniques. The overall RMS differences for all stations are 1 cm for positions and 1.5 mm/yr for velocities, whereas for about 15 sites (5%) the discrepancies for velocities exceed 2 cm/yr, e.g. Beijing (GPS, SLR), Trieste (SLR), Bear Lake (SLR), Albuquerque (SLR), Yozgat (SLR).

Table 2: RMS residuals for positions and site velocities after 14 parameter Helmert transformation between official ITRF2000 and the combined solution ITRF2000_DGFI.P.

Technique	***# Stations***	***Positions [mm]***	***Velocities [mm/yr]***
VLBI	86	7,8	0,6
SLR	95	19,1	2,8
GPS	147	4,5	1,5

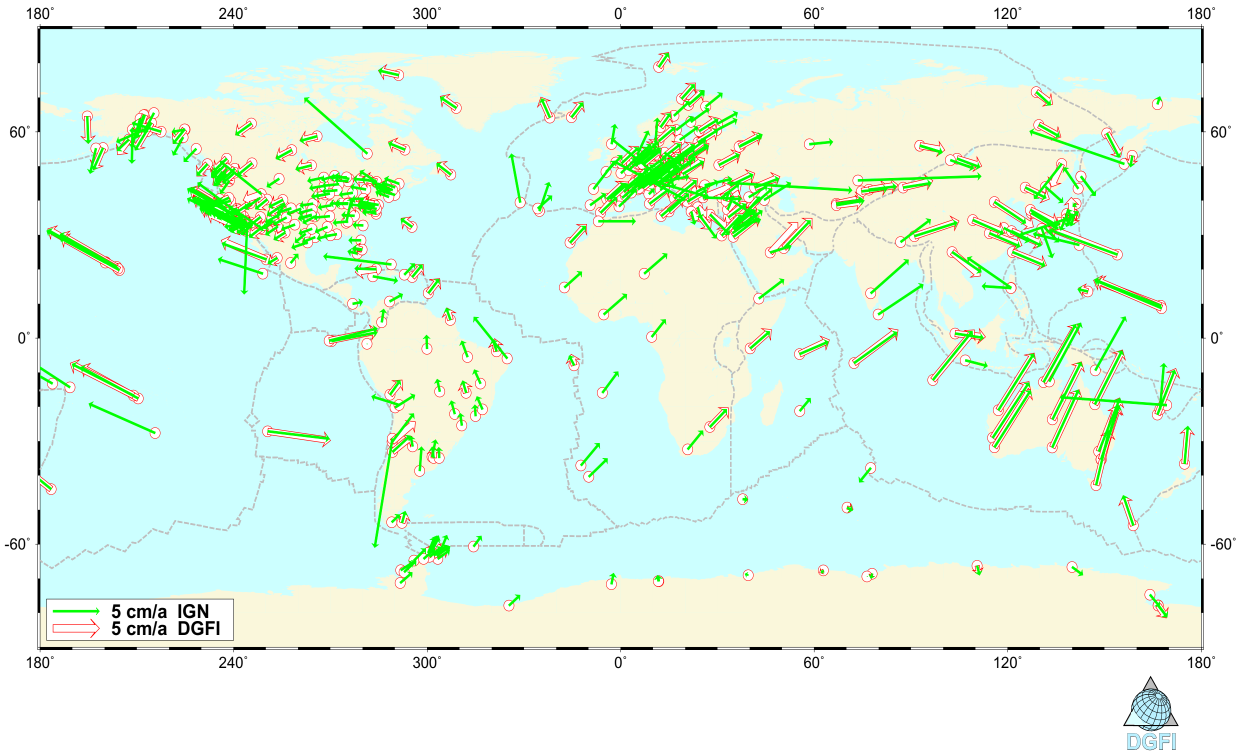
Summary and Recommendations

The re-organization of the ITRS section was an important step to achieve further improvements of the ITRS products. Like within all the space geodetic services, it is an indispensable requirement to have sufficient redundancy to ensure the reliability and a quality control of results. The comparison between the official ITRF2000 and the ITRF2000_DGFI.P combined solution shows a good agreement between both realizations with regard to the definition of the origin and the scale. For by far most of the ITRF stations the positions and site velocities between both ITRS realizations agree to better than 1 cm, and 1–2 mm/yr respectively. Further investigations in cooperation with IGN are necessary to analyse the significant differences, which exist for some of the stations.

Reduction of constraints

One serious problem of the combination is the reduction of the a priori datum constraints which normally are included in the solutions. The input solutions submitted for the ITRF2000 realization were classified to include loose, minimum, or removable constraints. We found remarkable contradictions with respect to these declarations. In particular the solutions defined as loosely or minimally constrained included often tremendous contraints. For some of the ITRF2000 input solutions these constraints could not be removed. If one neglects these constraints, significant biases and systematic effects might be introduced into the combination results. To overcome this problem, we recommend for future ITRF submissions, that unconstrained normal equations in addition to / or instead of solutions with variance-covariance matrices should be provided. For those analysis centres preferring to submit variance-covariance matrices, it should be mandatory to report all constraints properly.

Figure 1: Comparison of site velocities derived from ITRF2000 and ITRF2000_DGFI.P solution.



IERS network

Currently, the official ITRF2000 includes positions for about 800 stations located at about 500 sites. For these stations (sites), the standard deviations for positions and velocities range from 1 mm to 50 m (!), and < 1 mm/yr up to 3 m/yr (!), respectively. The main reason for these large variations is that the type and amount of data is quite heterogeneous. The data time span for the ITRF stations ranges from less than 1 month (!) for some mobile SLR and VLBI stations and up to 20 years for permanently operating stations. In case of GPS, stations with observation times less than one year and also regional solutions for densification networks were included in the ITRF2000. The spectrum of standard deviations for ITRF2000 site velocities is shown below:

–	< 1cm/yr	for 360 sites (75%)
–	1 cm/yr – 10 cm/yr	for 89 sites (19%)
–	10 cm/yr – 1 m/yr	for 23 sites (5%)
–	> 1 m/yr	for 5 sites (1%)

From our point of view, the current definition of the IERS network does not fully satisfy accuracy, reliability and homogeneity requirements of a precise reference frame. Therefore, we propose that a re-definition of the IERS network according to well-defined criteria should be discussed within the IERS. The main focus in this context should be the highest possible long-term reliability of the frame.

ITRF products

At present, the ITRF products are computed independently of the other IERS products (ICRS, EOPs). They contain a set of station coordinates at a reference epoch and station velocities, which are assumed to be constant (linear). It is obvious that the current specification of the ITRS products has several shortcomings. The assumption of constant site velocities is not true in reality, since several geophysical phenomena may vary as a non-linear function of time (e.g. seismic or volcanic effects, deformations at plate boundary zones, local effects). Therefore, alternative – and probably more realistic – representations for the time evolution of the ITRS should be discussed (e.g. time series of station positions). The products should be defined in such a way that the consistency between ITRS, ICRS and EOPs is ensured to the highest possible extent. Among others these aspects have to be considered for the implementation and specification of future ITRS products.

Detlef Angermann, Hermann Drewes, Klaus Kaniuth,
Manuela Krügel, Horst Müller, Wolfgang Seemüller

3.6.1.2 Institut Géographique National

This report summarizes the activities of the IERS ITRS Combination Centre at the Institut Géographique National (IGN) during the year 2001.

The main activities are:

- Data analysis and Software enhancement
- ITRF2000 project

Data analysis and Software enhancement

With interaction of IERS Analysis Centers (AC), individual solutions from the different techniques are frequently evaluated and tested, in order to improve the individual analyses as well as the ITRF combination. Thus both the individual ACs as well as the ITRF Section regularly test new analysis strategies. This cooperation between the IERS ACs and the ITRF Section is vital for quality control and improvement of IERS products. To achieve this goal, the software package Combination and Analysis of Terrestrial Reference Frames (CATREF), developed by the ITRF Section, is regularly updated and enhanced in order to perform proper analysis of the different solutions performed by the IERS ACs. In particular modeling of the Earth Orientation Parameters (EOP) is now included in the CATREF software, to be able to combine concisely and coherently station positions/velocities and EOPs.

ITRF2000 Project

A great part of the activity was devoted to the preparation and publication of the ITRF2000 solution. The ITRF2000 is intended to be a Standard and densified solution for a wide application community (geodesy, cartography, navigation, etc.).

The ITRF2000 was published in March 2001 and all results and related files are available at <http://lareg.ensg.ign.fr/ITRF/ITRF2000>. Moreover, a detailed article on the ITRF2000 technical description as well as geodetic and geophysical results is submitted to the Journal of Geophysical Research.

The ITRF2000 solution is the most dense and accurate frame ever developed, containing about 800 stations located on about 500 sites. It has been achieved by simultaneous combination of positions and velocities using full variance/covariance matrices of the individual solutions provided by the IERS Analysis Centers. It includes core stations observed by VLBI, LLR, SLR, GPS and DORIS (usually used in previous ITRF versions) as well as regional GPS networks for its densification (Alaska, Antarctica, Asia, Europe, North and South Americas and Pacific). Figure 1 shows the distribution of the primary sites of ITRF2000 highlighting the collocated techniques.

The ITRF2000 is intended to have an accurate datum definition, achieved as follows:

- the origin and its rate are defined by a weighted average of most consistent SLR solutions;

- the scale and its rate are defined by a weighted average of VLBI and most consistent SLR solutions. Unlike the ITRF97 scale, expressed in the Geocentric Coordinate Time-frame, that of the ITRF2000 is expressed in Terrestrial Time-frame. The effect of this change on the scale factor is 0.70 ppb (10^{-9}).

- the orientation is aligned to that of ITRF97 at 1997.0 epoch and its rate to be such that there is no-net-rotation rate with respect to NNR-NUVEL-1A. Note that the orientation as well as its rate are defined upon a selection of ITRF sites with high geodetic quality.

The ITRF2000 long-term stability, evaluated over 10 years, is estimated to be better than 4 mm in origin and better than 0.5 ppb in scale, equivalent to a shift in station heights of approximately 3 mm over the Earth's surface. Moreover, one of the important ITRF2000 results is that there is a statically significant disagreement between ITRF2000 and NUVEL-1A model in terms of relative tectonic plate motions. Although the ITRF2000 orientation rate is aligned to that of NNR-NUVEL-1A, per-plate residuals between the two corresponding velocity fields appear to be significant as shown in Figure 2. This per-plate residual behavior indicates the inadequacy of NUVEL-1A relative model to describe the current plate motions as seen by ITRF2000 results. Meanwhile it should be emphasized that these differences do not at all disrupt the internal consistency of the ITRF2000, simply because the alignment to NNR-NUVEL-1A defines the ITRF2000 orientation rate and nothing more. On the other hand, it is important to emphasize that the goal of aligning ITRF2000 to the NNR-NUVEL-1A model is to apply, implicitly, the No-Net-Rotation Condition or, equivalently, to realize a Tisserand Frame. The ITRF choice of the No-Net-Rotation Condition is dictated by the fact that the Tisserand axes frame is used in the theory of Earth rotation, having the property to minimize the Earth's crust motion and deformation that would affect the Earth Orientation Parameters. Analysis of the ITRF2000 velocity field demonstrated that the ITRF2000 satisfies the NNR condition at the 1 mm/y level.

Figure 1: ITRF2000 Primary Network

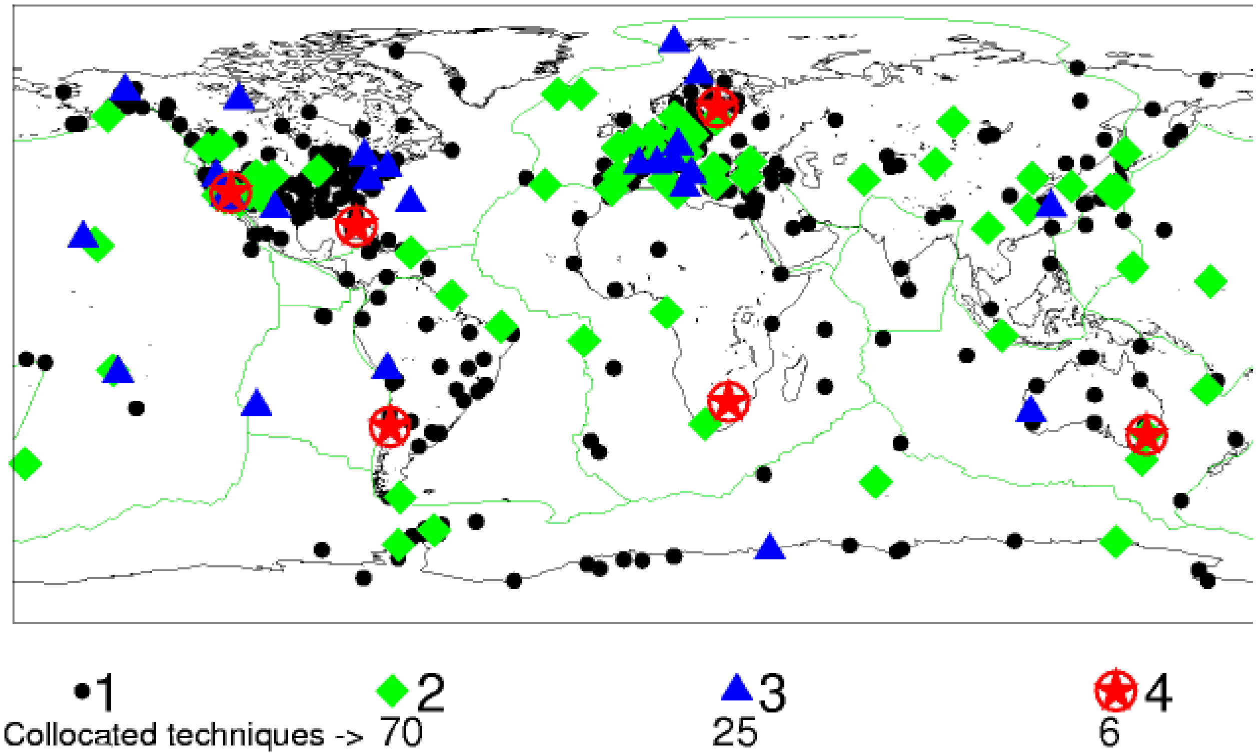
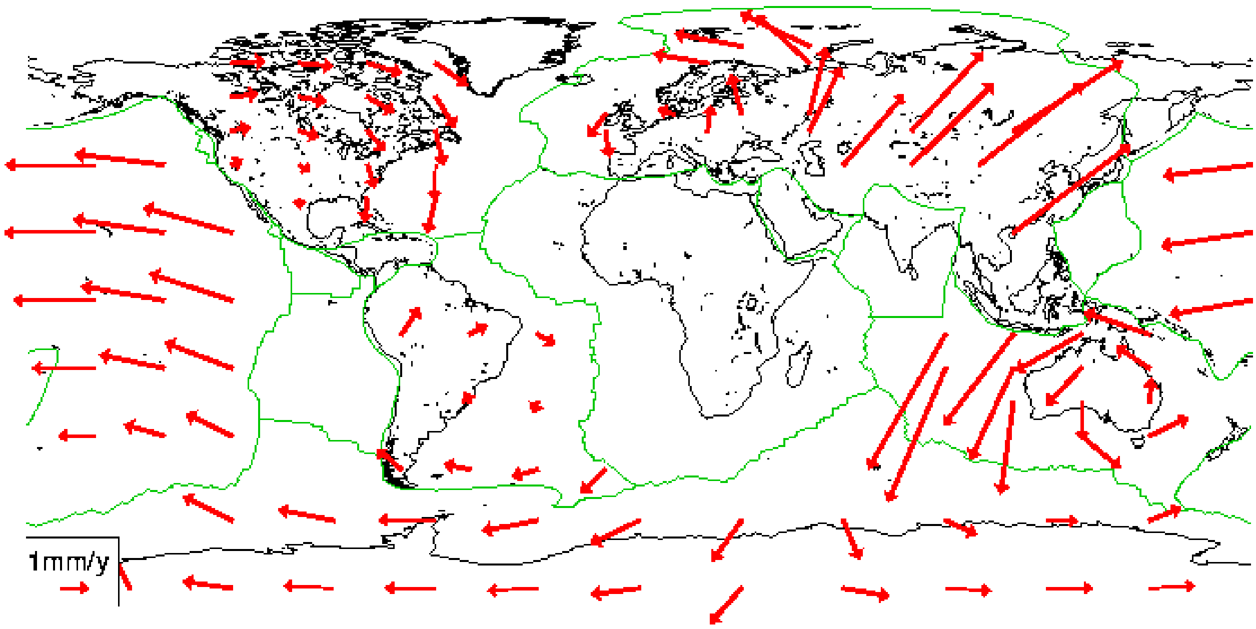


Figure 2. ITRF2000 and NNR-NUVEL-1A velocity differences



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Zuheir Altamimi, Claude Boucher,
Patrick Sillard, Martine Feissel

3.6.2 Combination Research Centres

3.6.2.1 Astronomical Institute, Academy of Sciences of the Czech Republic, and Department of Geodesy, Czech Technical University, Prague

The Combination Research Centre in Prague works principally in two different directions. The first direction, concerning only the combination of some of the Earth Orientation Parameters, led to the proposal of a 'combined smoothing' algorithm that takes into consideration different accuracy of different techniques in different frequencies. The method brought qualitatively new results based on the combination of VLBI and GPS observations, namely in combining UT1 with LOD in the interval 1993.5–2001.0 and celestial pole offsets with their rates in the interval 1997.0–2000.0. It was demonstrated that the GPS-based rates suffer from long-periodic systematic errors that must be removed before the combination, and that using these data improves the solution in the short-periodic part.

Another direction of research is combining particular solutions of different techniques for the simultaneous determination of EOP and station coordinates. From the individual techniques and epochs, the position vectors of the stations are restored in the celestial reference frame and combined to obtain corrected EOP. Transformation parameters to the station coordinates are then derived for each input solution.

Jan Vondrák, Jan Kostelecký

3.6.2.2 Deutsches Geodätisches Forschungsinstitut (DGFI)

Introduction

The IERS Combination Research Centres (CRC) are responsible for the development of methods for combining data and/or products emanating from the different techniques (VLBI, SLR, GPS, DORIS, etc.). The aim is to achieve further improvements for the combination of all space techniques involved in order to generate highly accurate and consistent IERS products. Within the new IERS the Forschungsgruppe Satellitengeodäsie, FGS (DGFI, FESG, GIUB) acts as a joint CRC. In this report we summarize the major activities of the CRC at DGFI. The work within the CRC is closely related to the ITRS Combination Centre at DGFI. During the year 2001 the activities were mainly concentrated on investigations and developments with regard to ITRS relevant issues. More information is available at the DGFI web site, at URL
<http://www.dgfi.badw.de/dgfi/IERS/>.

Software Development

DGFI has developed and/or employs various software packages for processing different space-technique observations, e.g. Bernese (GPS), DOGS (SLR, in future also DORIS), OCCAM (VLBI) and DOGS-CS for the combination. Further improvements of these software packages, including documentation and detailed description have been performed to fulfill the tasks of a CRC properly. Furthermore software for validation and analysis of input solutions (e.g. SINEX format, constraints, rank defects) and for the quality control of the combination results has been developed.

Combination methodology

Some major activities are summarized below:

- In principle, the combination strategy can be performed on different levels (e.g. observations, normal equations, solutions). From our experience within the ITRS Combination Centre it follows that the reconstruction of unconstrained normal equations from the individual SINEX solutions is in many cases difficult or even impossible. Therefore we recommend that unconstrained normal equations in addition to / or instead of solutions with variance-covariance matrices should be provided. Then the combination could be performed directly on the normal equation level without removing constraints.
- Regarding the parameter definition we investigated whether the current ITRS products (positions and linear station velocities) are appropriate also for the future. In this context we analysed site position time series with regard to non-linear effects, periodic signals, etc.
- Investigations and software developments concerning the weighting of solutions for intra- and inter-technique combination were performed.

– The eccentricities (local ties) are important to combine different space technique solutions into a common reference frame. Therefore, we concentrated on the validation of local ties and on their handling in the combination. In DOGS-CS the eccentricities are applied as observations with appropriate weights or with variance-covariance matrix.
– Concerning the datum definition we analysed the contribution of individual space techniques. For the definition of the kinematic datum we propose to use kinematic models based on geodetic observations (e.g. APKIM2000) instead of geophysical models (e.g. NNR NUVEL-1A) to ensure that the no net rotation condition is more accurately fulfilled.

Analysis of ITRF2000 input solutions

The analysis of ITRF2000 input solutions is related to the work of the ITRS Combination Centre at DGFI. Major activities were:
– Analysis of individual solutions with regard to constraints, reconstruction of unconstrained normal equations, rank defects, etc.
– Reviewing the differences between individual solutions which reach up to 5 cm for the origin and a few ppb for the global scale (see <http://lareg.ensg.ign.fr/ITRF/ITRF2000/T.gif> and <D.gif>). Further improvements of the ITRF require the analysis of these differences with respect to systematic effects, model differences, constraints, solution strategies, etc.

VLBI solution

DGFI re-analysed 2230 single VLBI sessions with the software OCCAM 5.0. The normal equations of these single session solutions were accumulated with DOGS-CS to a 18 years solution for coordinates and velocities for 47 stations. The results were used to analyse position time series of the VLBI stations and to participate in IVS pilot projects on comparison/combination of EOPs.

SLR solution

With the software package DOGS we computed a 20 years SLR solution based on laser ranging data to Lageos-1 & 2 of the global ILRS tracking network in the form of weekly arc solutions to investigate the time evolution of an SLR reference frame and site position time series.

Intra-technique combination: ILRS pilot projects (station positions and EOPs)

DGFI participated in the ILRS pilot projects (positions and EOPs) aiming at the computation of a time series of 4-weeks coordinates solutions for the global network of SLR stations and of daily EOPs, and the comparison and/or combination of the solutions provided by individual ILRS Analysis Centres and Associate Analysis Centres <ftp://ilrs.gsfc.nasa.gov/pub/slr/ilrsac/products/pos+eop>.

Detlef Angermann, Michael Gerstl, Rainer Kelm,
Barbara Meisel, Volker Tesmer

3.6.2.3 Forschungseinrichtung Satellitengeodäsie, Technical University of Munich (FESG)

Research Activities

The research activities at FESG as a Combination Research Centre of the IERS can be divided into four major topics:

– Analysis and combination of sub-daily Earth Rotation Parameter (ERP) series,
– Analysis and combination of nutation series,
– Rigorous combination of ITRF, EOPs and ICRF,
– Study contributions of Lunar Laser Ranging (LLR) to the IERS products.

The work is done in close cooperation with the DGFI (Deutsches Geodätisches Forschungsinstitut, Munich, Germany), the GIUB (Geodätisches Institut, University Bonn, Germany), and the GFZ (GeoForschungsZentrum Potsdam, Germany), the major activities being funded by Geotechnologien-Projekt of the German BMBF (Bundesministerium für Bildung und Forschung) .

The research activities of the FESG CRC started in September 2001, when the corresponding funding was obtained.

Sub-Daily Earth Rotation Series

As a first step, time series of Earth Rotation Parameters (ERP: pole coordinates, UT1) from different space geodetic techniques with a sub-daily resolution have been analysed and compared to assess the quality of the sub-daily ERP estimates, especially for time series from GPS and VLBI. After analysing the individual solutions first tests on the combination of the sub-daily series of ERPs were performed. The most recent results of these analyses were presented at the IAG Symposium in Budapest in September 2001. As a final goal it is planned to

(1) routinely generate combined ERP series with sub-daily resolution as a new IERS product to be used for studies in Earth rotation and geophysics,
(2) to compute the amplitudes of the ocean tide effects on Earth rotation. Comparing and combining the amplitudes of different space geodetic techniques (GPS, VLBI, SLR, altimetry) an optimal model for the correction of semi-diurnal and diurnal terms caused by the ocean tides will be generated and made available to the IERS.

Nutation Series

We started to analyse in detail the series of nutation parameters determined by VLBI (Goddard Space Flight Center, NASA) and the series of nutation rates determined by GPS (CODE Analysis Center of the IGS, AIUB). Other techniques and analysis centres will be included as soon as nutation or nutation rate series become available. From the analyses and comparison of the individual series we can get information about systematic effects between the different techniques. Combined nutation series could become a new product of the IERS in future. From the nutation series we may also compute the amplitudes of the most important nutation terms. These estimated amplitudes may be used to validate the present nutation models of the IERS.

Combination of ITRF+EOP+ICRF

The common and consistent combination of terrestrial reference frame (TRF) together with Earth Orientation Parameters (EOPs) and inertial reference frame (CRF) is a big field of research within the IERS and the FESG is contributing to develop new combination strategies. At the moment only TRF and EOPs can be combined with the available software, based on normal equations. The combination tests that were already done have been limited so far to intra-technique combination of GPS solutions from the different analysis centres, but the software package is presently being modified to work for an inter-technique combination using the local tie information and including a weighting strategy. Expertise gained from both research topics mentioned before, i.e., sub-daily Earth rotation series and nutation series, will be very beneficial to a rigorous combination of ITRF, EOPs and ICRF.

Contributions of LLR to the IERS Products

This research topic is performed in close cooperation with the IAPG (Institute for Astronomical and Physical Geodesy, TU Munich). The only LLR solution contributing to the ITRF2000 was produced by the FESG. With this CRC activity we plan to study in detail, to what extent LLR solutions may contribute to the various IERS products (station coordinates and velocities, EOPs, ...) and which additional information may be obtained from LLR solutions (as, e.g., relativistic parameters or tidal parameters). To perform these studies the current LLR software has to be updated to the most recent IERS standards and modified to allow the combination of the results (SINEX files) with those of other techniques. It is the goal to periodically produce LLR solutions as a contribution to the IERS products.

Markus Rothacher, Daniela Thaller, Robert Dill

3.6.2.4 Forsvarets forskningsinstitutt (FFI)

Introduction

Forsvarets forskningsinstitutt (FFI, Norwegian Defence Research Establishment) has during the last 19 years developed a software package called GEOSAT (Andersen, 1995) for the combined analysis of VLBI, GPS, SLR and other types of satellite tracking data (GLONASS, DORIS, PRARE and altimetry). The observations are combined at the observation level with a consistent model and consistent analysis strategies. The data processing is automized except for some manual editing of the SLR observations.

In the combined analysis of VLBI, GPS and SLR observations the data are processed in arcs of 24 hours defined by the duration of the VLBI session. The result of each analyzed arc is a state vector of estimated parameter corrections and a Square Root Information Array (SRIF) containing parameter variances and correlations. The individual arc results are combined into a multi-year global solution using a Combined Square Root Information Filter and Smoother program called CSRIFS. With the CSRIFS program any parameter can either be treated as a constant or stochastic parameter between the arcs. The estimation of multi-day stochastic parameters is possible and extensively used in the analyses.

Analysis strategy

Presently, the most important stochastic parameters of the global level state vector are the following: Radio source coordinates (1d resolution) of sources with structure index 3 or 4, geocentre coordinates (3d resolution), Earth orientation parameters (1d), the C21 and S21 gravity coefficients (6d), satellite independent SLR ranging biases (15d), Solar radiation pressure scaling and empirical drag of the Lageos satellites (3d), and GPS receiver antenna eccentricity vectors (station dependent time resolution to account for instrumental changes). The reason for including the two gravity coefficients is to account for the fact that errors in the gravity field will map into the estimates of polar motion derived from satellite tracking data. In order to be consistent with VLBI, which is almost independent of gravity, these parameters must be estimated.

The main constant parameters of the global state vector are monument coordinates and velocities, GPS and/or SLR eccentricity vectors relative to the station monument if it is a colocated station, radio source coordinates, relative zenith delay between VLBI and GPS at colocated stations (to account for differences in antenna heights), VLBI antenna axis offsets, and GPS satellite transmitter phase centre z-coordinate offset and nadir-dependent variation (relative to the satellite body-fixed reference frame). The commonly adopted z-coordinates for the effective phase centre of the GPS transmitter antennas are probably wrong by 1-2 meters.

Results show that the z-coordinate, as a function of the nadir angle, can be determined to a formal precision of some centimeters (1 sigma). Using the IGS z-coordinate values will result in a scale inconsistent with SLR and VLBI by several ppb. This means that most, but not all, of the error in the GPS phase centre offset is absorbed by the estimated clock and ambiguity parameters. However, the phase centre variation as a function of the nadir angle is not absorbed by the estimates of any of the parameters. The phase centre variation is within approximately 20 mm. One value is estimated for each of the Block II/IIA and Block IIR satellite types. Individual estimates for the different satellites of a specific type show remarkable similarities regarding the nadir dependency.

The status of the analyses is that approximately 3214 daily SLR arcs (with Lageos I & II data from 1 Jan 1993 to 31 Dec 2001) have been processed where 744 arcs are combinations with VLBI and approximately 200 arcs are combinations with VLBI, GPS and SLR. Typically, 60 GPS stations are included in each arc. These 3214 arcs have been combined into a global solution using the CSRIFS program. A program called CSRIFS-IERS reads the output of CSRIFS and estimates a time dependent transformation from the internal terrestrial and celestial reference frames to an ITRF (presently ITRF2000) and an IERS Celestial reference frame (presently ICRF-95.ext). Since the estimated Earth orientation parameters in principle are 100 % consistent with the internal reference frames the time dependent transformation parameters can be applied to transform the EOP estimates to IERS for comparison with the IERS EOP products. A possible inconsistency between the IERS reference frames and the IERS EOP estimates should in principle be detectable. The CSRIFS-IERS automatically generates SINEX files for the terrestrial and celestial reference frames and the EOPs. These files can be directly submitted to the IERS product centres.

During the last year the following improvements have taken place in the GEOSAT software:

- The DE405 planetary ephemerides have been implemented.
- The planets Mercury, Mars, Uranus, Neptune and Pluto have been included.
- The IERS-2000 VLBI observation model has been implemented.
- The Mendes et al. SLR refraction model has been implemented.
- The following GPS satellites have been down-weighted: PRN 2, 15, 17, 21, and 23.
- A constant GPS satellite phase centre offset (z-coordinate) for each of the Block II/IIA and Block IIR satellite types has been estimated.

- Nadir-dependent GPS satellite phase centre variations for each of the satellite types have been estimated.

All improvements listed above have been applied in the analysis of the 3214 arcs.

The results from a corresponding analysis, excluding the GPS data, have been submitted to the ITRS Centre, the Rapid Service/ Prediction Centre and the Earth Orientation Centre of the IERS.

References

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Per Helge Andersen

3.6.2.5 Geodetic Institute of the University of Bonn (GIUB)

Introduction

The Geodetic Institute of the University of Bonn (GIUB) is a member of the German Forschungsgruppe Satellitengeodäsie (FGS) and contributes to its joint IERS Combination Research Centre together with the Deutsches Geodätisches Forschungsinstitut (DGFI). The activities of the two institutes are coordinated by regular working meetings of the two groups involved. GIUB maintains the office of the Analysis Coordinator of the International VLBI Service for Geodesy and Astrometry (IVS) regularly providing VLBI EOP results combined from inputs of up to six IVS Analysis Centres. The work of the CRC at GIUB is mainly concentrated on improvements of the combination technology contributing to both the IERS and the IVS combination efforts.

Combination procedures

One of the topics covered in combination research effort is the extension of the stochastic model which is underlying the combination strategy. In the process of automatic combination the detection of outliers in the input data is of great importance in order to increase the reliability of the combined product. A method for checking the input data and eliminating outliers was developed and is now regularly applied in the combination process.

The use of ITRF2000 station coordinates as the basis for the combined series is the most recent step towards the generation of a consistent chain from the quasi-inertial frame of radio sources to a commonly accepted conventional terrestrial reference system. While the first combined series was referred to the IERS C04 series through constant biases, a new combined series is consistently linked to ITRF2000. This new series was first published on March 1st, 2002, and is now updated routinely.

Comparisons of the combined IVS series with EOP series of other techniques or combination products where other techniques play an important role have been carried out in order to get a realistic assessment of the quality of the current combination strategy.

IVS Analysis Pilot Projects

Two IVS Analysis Pilot Projects have been initiated in order to study the effects of fixed reference frames and of software package dependent systematics. Several aspects of the combination process became clearer through these pilot projects and feedback has been given to the IVS Analysis Centres on the quality of their submissions.

Axel Nothnagel, Dorothee Fischer, Christoph Steinforth

3.6.2.6 GeoForschungsZentrum Potsdam (GFZ)

The objectives of the GFZ CRC are:

- Study the possible systematic error sources of various space techniques (effects on translation, scale, rotation).
- Develop new combination methods to benefit from the advantages of each technique.
- Investigate the effect of the time variable gravity field on the reference frame and further develop the EPOS software at GFZ to enable it to solve the time-variable gravity field together with the reference frame.

During 2001 our efforts were focused on:

(1) Study the effects of the uncertainty of the geopotential constant GM on various satellite techniques.

The major results are:

- The effect of GM on the scale of satellite orbits is different from that on the scale of a reference frame. The latter depends on the height of the satellite(s) and on the tracking technique(s), while the former does not.
- The effect of GM on the scale of a GPS terrestrial frame is very small because the clock solution (or double difference procedure) absorbs most of the GM error.
- As far as the scales of terrestrial frames are concerned, the uncertainty in the GPS satellite antenna phase centre offset (z-direction) is almost equivalent to an error in GM. But the uncertainty in the currently available GM is much smaller than that of the z-offset. Therefore the z-offset could be one of the major scale error sources of the GPS terrestrial frame, whereas GM could not.

These findings were presented at the IAG Scientific Assembly (“Vistas for Geodesy in the New Millennium”), 2-7 Sept. 2001, Budapest, Hungary. A number of papers are published or submitted.

(2) Software development and test runs

Currently, the most widely used method for LEO orbit determination is a so-called two-step method in which the GPS orbits are fixed. We have undertaken to combine CHAMP SST GPS data with the ground GPS data to solve the LEO precise orbits together with the GPS orbits and the station coordinates (one-step method). At the first stage the aims are to study the advantages (and disadvantages) of these two methods, and to investigate possible contributions of LEO data to the GPS solutions.

Sheng Yuan Zhu

3.6.2.7 Groupe de Recherches de Géodésie Spatiale (GRGS)

Report not available.

3.6.2.8 Institut Géographique National (IGN)

Space Geodesy techniques make available station positions and EOPs on a regular basis. For many years, IERS has shown the interest of combining data coming from various techniques to improve overall reliability. It is now time to study the implications of realizing terrestrial reference systems through a consistent time series of station positions and EOPs. This is exactly what the IERS Combination Research Centre of IGN aims at.

Some preliminary tests have been made after having developed a new software during the year 2001. The software deals with a mixed filtering and deterministic approach. A test combination of 3 months of GPS, SLR and DORIS data has been done including time series of station positions and EOPs. The results have been presented at EGS general assembly in Nice (2002) and a detailed paper should be published in EGS proceedings (*Multi-technique combination of terrestrial reference frame time series*, by P. Sillard, Z. Altamimi and C. Boucher).

The basic model of the combination, for a parameter P (say a station coordinate or an EOP) is the following:

$$\begin{aligned} P(t) &= P(t - \delta t) + \varepsilon(\delta t) \\ \mathrm{E}[\varepsilon(\delta t)] &= 0 \\ \mathrm{var}[\varepsilon(\delta t)] &= [\sigma(\delta t)]^2 \end{aligned}$$

As usual, $\sigma(\delta t)$ is a random variable with zero mean and standard deviation depending on δt. E and var are respectively mathematical expectancy and variance. All the parameters are modelled as random walk whose prediction covariance is increasing with time. This covariance is adjusted through an Helmert variance component estimation process. Physically, previous equation says that the process P is continuous in time and the continuity is transcribed stochastically through a time dependent constraint.

In addition to the previous state model, observation equations hold between parameters and observations (which in case of set of station coordinates combination are more or less of similar types).

The main original idea is the estimation of the random walk covariance (the term $[\sigma(\delta t)]^2$ in the above equation). The main conclusion of this first test is that the principle of filtering that is made only on EOPs up to now should be extended to station coordinates. This is what we intend to do in the year 2002.

Patrick Sillard, Zuheir Altamimi, Claude Boucher

3.6.2.9 Institute of Applied Astronomy (IAA)

Research groups and staff

Two research groups of the Institute of Applied Astronomy of the Russian Academy of Sciences (IAA) are involved in the IERS CRC related activity:

1. Laboratory of Space Geodesy and Earth Rotation (LSGER)
   Zinovy Malkin (head), Natalia Panafidina
   Contact: malkin@quasar.ipa.nw.ru

2. Laboratory of Ephemeris Astronomy (LEA)
   George Krasinsky, Nadejda Shuygina
   Contact: kra@quasar.ipa.nw.ru

Activities

LSGER group

1. Comparison and combination of EOP series, TRF and CRF realizations in the framework of the IAA EOP Service activity

The main topics of investigations in this direction in 2001 included:

1. Comparison of EOP series, TRF and CRF realizations for investigation of systematic differences between them.
2. Comparison of VLBI EOP series obtained with different software and from different observational programs.
3. Comparative analysis of the VLBI nutation series, their combination and comparison with model.

The nearest goal of this investigations is the derivation of combined EOP series from VLBI, SLR and GPS solutions routinely computed at the IAA.

2. Computations of independent GPS/EPN coordinate time series.

The basis of this project is using a non-fiducial (free network) strategy for computation of station coordinates. This strategy has some evident advantages:

1. Such a solution does not cause a distortion of the network.
2. More stations can be used for orientation of a network which makes the final orientation of the solution more reliable and dependant to a lesser degree on unmodelled errors in the coordinates of the fiducial stations.
3. Such a solution can be easily transformed to any reference system and re-transformed to another one using a much simpler procedure than that needed for removing constraints.

At the first stage of the project we re-processed original GPS observations for selected EPN subnetwork. That processing was made in three steps:

1. Computation of a daily free network solution.
2. Computation of a weekly free network solution.
3. Transformation of weekly free network solution to ITRF.

This approach can provide a fully independent solution free of network distortion. Unfortunately, this way of computation requires too much resources and it is practically impossible to re-process all EPN observations in such a way.

The second stage of our work is re-processing of available combined weekly EPN solutions produced at CODE and BKG. This processing is made in two steps:

1. Removing constraints from the official EPN solutions.
2. Transformation of obtained quasi-free-network solution to ITRF.

We plan to begin regular operative computation of this series in 2002 after solution of some remaining problems.

The third stage of the project is now under development. We plan to compute a new EPN combined solution based on independent combination of existing EPN Analysis Centers' solutions using a three step approach:

1. Removing the Analysis Center's specific constraints when necessary.
2. Computation of a weekly free network solution.
3. Final orientation of the weekly free network solution w.r.t. ITRF2000.

3. Participation in the IERS Analysis Campaign to align EOPs to ITRF2000

Five EOP solutions obtained from processing of VLBI, SLR and GPS observations were submitted to the IERS Analysis Coordinator: IAA01L83020, IAA02L93020, IAA03R84020, IAA04R80020, IAA05P00020. Besides, VLBI session TRF solutions for 1999 were provided.

LEA group

The main topic of investigations is the combination of space geodesy and other astronomical observations (optical, radar, Doppler) at the observational level in single processing using ERA software.

Experimental computation of combined SLR+VLBI series was begun in 1998 and advanced algorithms and software are under development. SLR observations of Lageos-1, Lageos-2, Etalon-1, Etalon-2 have been processed in the frame of the ILRS AWG Pilot Project "positioning + Earth orientation" and submitted to the AWG. The approach proposed by the AWG was expanded by experiments with a combined processing of the SLR observations with VLBI observations of the NEOS-A program for the same time interval.

In this way the contribution of SLR data not only to determination of the pole coordinates and LOD but also to evaluation of time variations of Celestial Pole could be provided. Kalman filtering was used both for modelling of the fast changing parameters of VLBI techniques (clock errors and atmosphere effects) and the time variations of the all five Earth Orientation Parameters. It appeared that in this way some fine effects in the variations of EOPs might be studied.

Zinovy Malkin, Natalia Panafidina,
George Krasinsky, Nadejda Shuygina

3.6.2.10 Jet Propulsion Laboratory (JPL)

JPL supports tracking and navigation of interplanetary spacecraft by using a Kalman filter to operationally combine and predict Earth orientation parameters twice-per-week. The EOP measurements used in the combination are taken by both in-house and extramural measurement programs. The resulting combined and predicted EOP series can be obtained by anonymous ftp to <ftp://euler.jpl.nasa.gov/keof/predictions>.

As part of this operational program, reference series of Earth orientation parameters are produced annually. The latest such reference series, SPACE2001, COMB2001, and POLE2001, can be obtained by anonymous ftp to

<ftp://euler.jpl.nasa.gov/keof/combinations/2001>.

A report describing their generation can also be downloaded from this same ftp site.

Research activities during the past year were largely concerned with exploring methods of improving the accuracy of the combined and predicted values. The stochastic model of the errors in the GPS LOD measurements used by the Kalman filter was updated, Earth orientation measurements from alternate sources were evaluated, and methods to improve the prediction of the EOPs were explored.

Richard Gross

Appendix 1: IERS Terms of Reference

The International Earth Rotation Service (IERS) was established in 1987 by the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG) and it began operation on 1 January 1988. IERS is a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS).

The primary objectives of the IERS are to serve the astronomical, geodetic and geophysical communities by providing the following:

- The International Celestial Reference System (ICRS) and its realization, the International Celestial Reference Frame (ICRF).
- The International Terrestrial Reference System (ITRS) and its realization, the International Terrestrial Reference Frame (ITRF).
- Earth orientation parameters required to study earth orientation variations and to transform between the ICRF and the ITRF.
- Geophysical data to interpret time/space variations in the ICRF, ITRF or earth orientation parameters, and model such variations.
- Standards, constants and models (i.e., conventions) encouraging international adherence.

IERS is composed of a broad spectrum of activities performed by governmental or selected commercial organizations.

IERS collects, archives and distributes products to satisfy the objectives of a wide range of applications, research and experimentation. These products include the following:

- International Celestial Reference Frame.
- International Terrestrial Reference Frame.
- Monthly earth orientation data.
- Daily rapid service estimates of near real-time earth orientation data and their predictions.
- Announcements of the differences between astronomical and civil time for time distribution by radio stations.
- Leap second announcements.
- Products related to global geophysical fluids such as mass and angular momentum distribution.
- Annual report and technical notes on conventions and other topics.
- Long term earth orientation information.

The accuracies of these products are sufficient to support current scientific and technical objectives including the following:

- Fundamental astronomical and geodetic reference systems.
- Monitoring and modeling earth rotation/orientation.
- Monitoring and modeling deformations of the solid earth.
- Monitoring mass variations in the geophysical fluids, including the atmosphere and the hydrosphere.
- Artificial satellite orbit determination.
- Geophysical and atmospheric research, studies of dynamical interactions between geophysical fluids and the solid earth.
- Space navigation.

The IERS accomplishes its mission through the following components:

- Technique Centers.
- Product Centers.
- Combination Center(s)
- Analysis Coordinator.
- Central Bureau.
- Directing Board.

Some of these components (e.g., Technique Centers) may be autonomous operations, structurally independent from IERS, but which cooperate with the IERS. A participating organization may also function as one or several of these components (except as a Directing Board).

TECHNIQUE CENTERS (TC)

The TCs generally are autonomous independent services, which cooperate with the IERS.

The TCs are responsible for developing and organizing the activities in each contributing observational technique to meet the objectives of the service. They are committed to produce operational products, without interruption, and at a specified time lag to meet requirements. The products are delivered to IERS using designated standards. The TCs provide, as a minimum, earth orientation parameters and related reference frame information, as well as other products as required.

The TCs exercise overall control of observations from their specific techniques, archiving, quality control and data processing including combination processing of data and/or products received from their participating organizations. TCs are the various international technique specific services: IGS, ILRS, IVS and possible future TCs e.g. DORIS.

PRODUCT CENTERS (PC)

PCs are responsible for the products of the IERS.

Such centers are the following:

- Earth Orientation Center, responsible for monitoring earth orientation parameters including long term consistency, publications for time dissemination and leap second announcements.
- Rapid Service/Prediction Center, responsible for publication of semiweekly (possibly daily?) bulletins of preliminary and predicted earth orientation parameters.
- Convention Center, under the guidance of the IERS Conventions Editorial Board, responsible for the maintenance of the IERS conventional models, constants and standards.
- ICRS Center, responsible for the maintenance of the ICRS/ICRF.
- ITRS Center, responsible for the maintenance of the ITRS/ITRF, including network coordination (design collocation, local ties, and site quality). For this purpose the Center is also responsible to provide the ITRS Combination Centers (see below) with specifications, and to evaluate their respective results.
- Global Geophysical Fluids Center, responsible for providing relevant geophysical data sets and related computational results to the scientific community.

COMBINATION CENTER(S)

- Combination Research Center(s) are responsible for the development of combinations from data and/or products emanating from the different techniques (TCs). These research combination solutions are provided to the Analysis Coordinator.
- ITRS Combination Center(s) are responsible to provide ITRF products by combining ITRF inputs from the TCs and others. Such products are provided to the ITRS Product Center.

IERS ANALYSIS COORDINATOR (AC)

The AC is responsible for the long-term and internal consistency of the IERS reference frames and other products. He is responsible for ensuring the appropriate combination of the TC products into the single set of official IERS products and the archiving of the products at the Central Bureau or elsewhere.

The AC serves for a four-year term, renewable once by the DB. The responsibility of the AC is to monitor the TC and PC activities to ensure that the IERS objectives are carried out. This is accomplished through direct contact with the independent TC Analysis Coordinators or equivalent. Specific expectations include quality control, performance evaluation, and continued development of appropriate analysis methods and standards. The AC interacts fully with the Central Bureau, the Product Centers and the Combination Research Center(s).

CENTRAL BUREAU (CB)

The Central Bureau is responsible for the general management of the IERS consistent with the directives and policies set by the Directing Board, i.e., acts as the executive arm of the Directing Board. The CB facilitates communications, coordinates activities, monitors operations, maintains documentation, archives products and relevant information and organizes reports, meetings and workshops.

Although the Chairperson of the Directing Board is the official representative of the IERS at external organizations, the CB is responsible for the day-to-day liaison with such organizations. The CB coordinates and publishes all documents required for the satisfactory planning and operation of the Service, including standards/conventions/specifications regarding the performance, functionality and configuration requirements of all elements of the Service including user interface functions.

The CB operates the communication center for the IERS. It distributes and/or maintains a hierarchy of documents and reports, both hard copy and electronic, including network information, standards, newsletters, electronic bulletin board, directories, summaries of performance and products, and an Annual Report.

DIRECTING BOARD (DB)

The Directing Board consists of the following members appointed for four-year terms, renewable once:

- Two representatives from each Technique Center to be selected by the Technique Center's governing board or equivalent. The two representatives will represent that technique regarding
    a. its network and coordination with other techniques,
    b. the details of the technical analyses.

It is desired that, as part of reciprocity agreements, IERS representatives are to become members of the Technique Centers' directing boards.

- One representative from each Product Center.
- One representative from the Combination Research Center(s).
- Representative of the Central Bureau.
- IERS Analysis Coordinator.
- Representatives of IAU, IAG/IUGG and FAGS.

The Chairperson is one of the members of the DB elected by the Board for a term of four years with the possibility of re-election for one additional term. The Chairperson does not vote, except in case of a tie. He/she is the official representative of IERS to external organizations.

The DB exercises general control over the activities of the service and modifies the organization as appropriate to maintain efficiency and reliability, while taking full advantage of the advances in technology and theory.

Most DB decisions are to be made by consensus or by a simple majority vote of the members present, provided that there is a quorum consisting of at least one half of the membership. In case of a lack of a quorum, the voting is by correspondence. Changes in the Terms of Reference and Chairperson of the DB can be made by a two third majority of the members of the DB.

For the DB to effectively assess the value of IERS services to the user communities, and to ensure that the service remains up to date and responsive to changing user needs, the DB will organize reviews of the IERS components at appropriate intervals. The DB will decide, on an annual basis, those components that are to be reviewed and from time to time may select other activities for review, as it deems appropriate. The Central Bureau provides the secretariat of the DB.

The Board shall meet at least annually and at such other times as shall be considered appropriate by the Chairperson or at the request of five members.

IERS ASSOCIATE MEMBERS

Persons representing organizations that participate in any of the IERS components, and who are not members of the Directing Board, are considered IERS Associate Members. Ex officio IERS Associate Members are the following persons:

IAG General Secretary

President of IAG Section II

President of IAG Commission VIII

President of IAG Section V

President of IAU Commission 19

President of IAU Commission 31

Head of IAU Division I

IERS CORRESPONDENTS

IERS Correspondents are persons on a mailing list maintained by the Central Bureau, who do not actively participate in the IERS but express interest in receiving IERS publications, wish to participate in workshops or scientific meetings organized by the IERS, or generally are interested in IERS activities.

April 20, 2002

Appendix 2: Contact addresses of the IERS Directing Board

Chair

Jan Vondrák
(address see below)

Analysis Coordinator

Markus Rothacher
Forschungseinrichtung Satellitengeodäsie
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Technische Universität München
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Product Centres Representatives

Earth Orientation Centre Representative

Daniel Gambis
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61, avenue de l'Observatoire
75014 Paris
France
phone: ++33-1-40512229
fax: ++33-1-40512291
e-mail: Daniel.Gambis@obspm.fr

Rapid Service/Prediction Centre Representative

N. N.

Conventions Centre Representative

Dennis D. McCarthy
U.S. Naval Observatory, Earth Orientation Department
3450 Massachusetts Avenue, NW
Washington, DC
USA
phone: ++1-202-762-1837
fax: ++1-202-762-1563
e-mail: dmc@maia.usno.navy.mil

ICRS Centre Representative

Jean Souchay
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61, avenue de l'Observatoire
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fax: ++33-1-40512291
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ITRS Centre Representative

Claude Boucher
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Laboratoire de Recherche en Geodesie
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Global Geophysical Fluids Centre Representative

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NASA's Goddard Space Flight Center
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USA
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Central Bureau Representative

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Combination Research Centres Representative

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Technique Centers Representatives

IGS Representatives

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IVS Representatives

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IDS Representative (observing status)

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Union Representatives

IAU Representative

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IAG / IUGG Representative

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FAGS Representative

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Appendix 3: Contact addresses of the IERS components

Technique Centres

International GPS Service (IGS)
IGS Central Bureau
Jet Propulsion Laboratory (JPL)
M/S 238-540, 4800 Oak Grove Drive
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e-mail: igscb@igscb.jpl.nasa.gov

IGS Representatives to the IERS Directing Board:
Carine Bruyninx, Robert Weber
IERS Representative to the IGS Directing Board:
Claude Boucher

International Laser Ranging Service (ILRS)
ILRS Central Bureau
NASA's Goddard Space Flight Center (GSFC), Code 920.1
Greenbelt, MD 20771, USA
phone: ++1-301-614-5969, fax: ++1-301-614-5970
e-mail: cb@ilrs.gsfc.nasa.gov

ILRS Representatives to the IERS Directing Board:
Ron Noomen, Peter Shelus
IERS Representative to the ILRS Directing Board:
Bob E. Schutz

International VLBI Service (IVS)
IVS Coordinating Center
National Earth Orientation Service, Code 920.1, GSFC
Greenbelt, MD 20771, USA
phone: ++1-301-286-9019, fax: ++1-301-286-0213
e-mail: ivscc@ivscc.gsfc.nasa.gov

IVS Representatives to the IERS Directing Board:
Chopo Ma, Axel Nothnagel
IERS Representative to the IVS Directing Board: Chopo Ma

International DORIS Service (IDS) - planned
Gilles Tavernier
CNES, DSO/ED/AL/MA - Bpi 2002
18, avenue Edouard Belin
31401 Toulouse Cedex 4, France
phone: ++33-5 61 27 37 76, fax : ++33-5 61 28 25 95
e-mail: Gilles.Tavernier@cnes.fr

DORIS representative to the IERS with observing status:
Pascal Willis

Product Centres

Earth Orientation Centre

Observatoire de Paris
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e-mail: iers@obspm.fr

Primary scientist and representative to the IERS Directing Board: Daniel Gambis

Rapid Service/Prediction Centre

U.S. Naval Observatory, Earth Orientation Department
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e-mail: ser7@maia.usno.navy.mil

Primary scientist and representative to the IERS Directing Board: N.N.; *managing*: Thomas Johnson

Convention Centre

U.S. Naval Observatory, Earth Orientation Department
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e-mail: dmc@maia.usno.navy.mil

Bureau International des Poids et Mesures
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e-mail: gpetit@bipm.fr

Primary scientists:
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Current representative to the IERS Directing Board:
Dennis D. McCarthy

ICRS Centre

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U.S. Naval Observatory, Earth Orientation Department
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Primary scientists:
Ralph A. Gaume (USNO), Jean Souchay (Obs. Paris)
Current representative to the IERS Directing Board:
Jean Souchay

ITRS Centre
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Ecole Nationale de Sciences Geographiques (ENSG)
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Primary scientist and representative to the IERS Directing Board: Claude Boucher

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Special Bureau for the Oceans
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Special Bureau for Tides
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Special Bureau for Gravity/Geocenter
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Special Bureau for Loading
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Combination Centres

ITRS Combination Centres

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Combination Research Centres

CRC representative to the IERS Directing Board: Sheng Yuan Zhu

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Forsvarets forskningsinstitutt (FFI, Norwegian Defence Research Establishment)
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Groupe de Recherches de Géodésie Spatiale (GRGS)
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Central Bureau

IERS Central Bureau
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Director: Bernd Richter
Scientific Assistant: Wolfgang R. Dick

Appendix 4: Electronic Access to IERS Products, Publications and Components

Central IERS web site

http://www.iers.org/

Please note that all other products, publications and centres may be accessed via this web site.

Products

Earth orientation data

Rapid data and predictions
Web access: http://maia.usno.navy.mil/
ftp access: `maia.usno.navy.mil` - directory `ser7`

Monthly earth orientation data
Web access: http://hpiers.obspm.fr/eop-pc/products/bulletins.html
ftp access: `hpiers.obspm.fr` - directory `iers/bul/bulb`

Long term earth orientation data
Web access: http://hpiers.obspm.fr/eop-pc/products/eopcomb.html
ftp access: `hpiers.obspm.fr` - directory `iers/eop`

Leap second announcements
Web access: http://hpiers.obspm.fr/eop-pc/products/bulletins.html
ftp access: `hpiers.obspm.fr` - directory `iers/bul/bulc`

Announcements of DUT1
Web access: http://hpiers.obspm.fr/eop-pc/products/bulletins.html
ftp access: `hpiers.obspm.fr` - directory `iers/bul/buld`

Conventions

Web access:
IERS Conventions 1996: http://maia.usno.navy.mil/conventions.html
IERS Conventions 2000 (in preparation):
http://maia.usno.navy.mil/conv2000.html

International Celestial Reference Frame

Web access: http://hpiers.obspm.fr/icrs-pc/
ftp access: `hpiers.obspm.fr` - directory `iers/icrf`

International Terrestrial Reference Frame

Web access: http://lareg.ensg.ign.fr/ITRF/
ftp access: `lareg.ensg.ign.fr` - directory `pub/itrf`

Geophysical fluids data

Web accesss: http://bowie.gsfc.nasa.gov/ggfc/

Publications

IERS Messages
http://www.iers.org/iers/publications/messages/

IERS Bulletins
http://maia.usno.navy.mil/ (Bulletin A)
http://hpiers.obspm.fr/eop-pc/products/bulletins.html
(Bulletins B, C, D)
http://www.iers.org/iers/publications/bulletins/

IERS Technical Notes
http://www.iers.org/iers/publications/tn/

IERS Annual Reports
http://www.iers.org/iers/publications/reports/

ITRF Mail
http://list.ensg.ign.fr/wws/arc/itrfmail

IERS Components

Directing Board
Web page: http://www.iers.org/iers/about/db/

Central Bureau
Web site: http://www.iers.org/

Analysis Coordinator
Web site: http://alpha.fesg.tu-muenchen.de/iers/

Product Centres

Earth Orientation Centre
Web site: http://hpiers.obspm.fr/eop-pc/

Rapid Service/Prediction Centre
Web site: http://maia.usno.navy.mil/

Convention Centre
Web page: http://www.iers.org/iers/pc/conv/

ICRS Centre
Web site: http://hpiers.obspm.fr/icrs-pc/

ITRS Centre
Web site: http://lareg.ensg.ign.fr/ITRF/

Global Geophysical Fluids Centre
Web site: http://bowie.gsfc.nasa.gov/ggfc/
Special Bureaus:
Special Bureau for the Atmosphere
Web site: http://www.aer.com/groups/diag/sb.html
Special Bureau for the Oceans
Web site: http://euler.jpl.nasa.gov/sbo/
Special Bureau for Tides
Web site: http://bowie.gsfc.nasa.gov/ggfc/tides/
Special Bureau for Hydrology
Web site: http://www.csr.utexas.edu/research/ggfc/
Special Bureau for Mantle
Web site: http://bowie.gsfc.nasa.gov/ggfc/mantle.htm
Special Bureau for the Core
Web site: http://www.astro.oma.be/SBC/main.html
Special Bureau for Gravity/Geocenter
Web site: http://sbgg.jpl.nasa.gov/
Special Bureau for Loading
Web site: http://www.gdiv.statkart.no/sbl/

Technique Centres

International GPS Service (IGS)
Web site: http://igscb.jpl.nasa.gov/

International Laser Ranging Service (ILRS)
Web site: http://ilrs.gsfc.nasa.gov/

International VLBI Service (IVS)
Web site: http://ivscc.gsfc.nasa.gov/

International DORIS Service (IDS) - planned
Web site: http://ids.cls.fr/

Combination Centres
ITRS Combination Centres

Deutsches Geodätisches Forschungsinstitut (DGFI)
Web site: http://www.dgfi.badw.de/dgfi/IERS/

Geomatics Canada, Geodetic Survey Division
Web page: http://www.iers.org/iers/itrscc/geocan/

Institut Géographique National (IGN)
Wep page: http://www.iers.org/iers/itrscc/ign/

Combination Research Centres

Web site: http://alpha.fesg.tu-muenchen.de/iers/

Astronomical Institute, Academy of Sciences of the Czech Republic, Prague
Web site: http://www.asu.cas.cz/~ron/ierscrc/

Deutsches Geodätisches Forschungsinstitut (DGFI)
Web site: http://dgfi.badw-muenchen.de/dgfi/WWW/D/d1_en.html

Forschungseinrichtung Satellitengeodäsie, Technical University Munich (FESG)
Web page: http://www.iers.org/iers/crc/fesg/

Forsvarets forskningsinstitutt (FFI, Norwegian Defence Research Establishment)
Web page: http://www.iers.org/iers/crc/ffi/

GeoForschungsZentrum Potsdam (GFZ)
Web page: http://www.iers.org/iers/crc/gfz/

Geodetic Institute of the University of Bonn (GIUB)
Web page: http://www.iers.org/iers/crc/giub/

Groupe de Recherches de Géodésie Spatiale (GRGS)
Web page: http://www.iers.org/iers/crc/grgs/

Institute of Applied Astronomy, St. Petersburg (IAA)
Web page: http://www.iers.org/iers/crc/iaa/

Institut Géographique National (IGN)
Web page: http://www.iers.org/iers/crc/ign/

Jet Propulsion Laboratory (JPL)
Web page: http://www.iers.org/iers/crc/jpl/

Appendix 5: Acronyms

AAM	Atmospheric Angular Momentum
AC	Analysis Centre
AC	Analysis Coordinator
AER	Atmospheric and Environmental Research Inc.
AGU	American Geophysical Union
APSG	Asia-Pacific Space Geodynamics
AUSLIG	Australian Surveying and Land Information Group (now: GEOSCIENCE AUSTRALIA - National Mapping Division)
AVISO	Archiving, Validation and Interpretation of Satellites Oceanographic data
AWG	Analysis Working Group
BIH	Bureau International de l'Heure
BIPM	Bureau International des Poids et Mesures
BKG	Bundesamt für Kartographie und Geodäsie
BKGI	BKG in cooperation with GIUB
CB	Central Bureau
CC	Combination Centre
CERGA	Centre d'Etudes et de Recherches Géodynamiques et Astronomiques
CDDIS	NASA Crustal Dynamics Data Information System
CGS	Centre di Geodesia Spatiale
CLS	Collecte, Localisation, Satellites
CMB	core-mantle boundary
CNES	Centre National d'Etude Spatiale
CODE	Centre for Orbit Determination in Europe
CORE	NASA Continuous Observations of the Rotation of the Earth
CRC	Combination Research Centre
CRF	Celestial Reference Frame
CRL	Communications Research Laboratory
CSR	Center for Space Research
CSTG	Commission on International Coordination of Space Techniques for Geodesy and Geodynamics
DANOF	Département d'Astronomie Fondamentale
DB	Directing Board
DEOS	Delft Institute for Earth-Oriented Space Research
DGFI	Deutsches Geodätisches Forschungsinstitut
DIODE	Détermination Immédiate d'Orbite par Doris Embarqué
DOMES	Directory Of MERIT Sites (originally; now of more general use)
DORIS	Doppler Orbit determination and Radiopositioning Integrated on Satellite
DUT	Delft University of Technology
DUT1	= UT1-UTC
EGS	European Geophysical Society
EMR	Energy, Mines and Resources Canada (replaced by NRCan)
ENSG	Ecole Nationale de Sciences Geographiques
EOC	Earth Orientation Centre
EOP	Earth Orientation Parameters
ERP	Earth Rotation Parameters
ESA	European Space Agency
ESOC	European Space Agency Operational Center
FAGS	Federation of Astronomical and Geophysical Data Analysis Services
FESG	Forschungseinrichtung Satellitengeodäsie, Technical University Munich
FFI	Forsvarets forskningsinstitutt
FTP	File Transfer Protocol
GAOUA	Main Astronomical Observatory of the Ukrainian Academy of Sciences
Gbps	Gigabit per second
GFZ	GeoForschungsZentrum Potsdam
GGFC	Global Geophysical Fluids Center
GIUB	Geodetic Institute of the University of Bonn
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRGS	Groupe de Recherches de Géodésie Spatiale
GSFC	Goddard Space Flight Center

IAA	Institute of Applied Astronomy, St. Petersburg
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
IDS	International DORIS Service
IERS	International Earth Rotation Service
IGG	Institute of Geodesy and Geophysics
IGLOSS	International GLONASS Service
IGN	Institut Géographique National
IGGOS	Integrated Global Geodetic Observing System
IGR	IGS rapid (orbit)
IGS	International GPS Service
IGU	IGS ‘ultra-rapid’ satellite orbits
ILRS	International Laser Ranging Service
INASAN	INstitut AStronomii Rossijskoj Akademii Nauk (Institute of Astronomy of the Russian Academy of Sciences)
IRIS	International Radio Interferometric Surveying
ISGN	International Space Geodetic and Gravimetric Network
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI
JCET	Joint Center for Earth System Technology, GSFC
JPL	Jet Propulsion Laboratory
LAREG	Laboratoire de Recherche en Geodesie
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LEO	Low Earth Orbit
LLR	Lunar Laser Ranging
LOD	Length of Day
mas	milliarcsecond(s)
MCC	Russian Mission Control Centre
MJD	Modified Julian Day
NASA	U.S. National Aeronautics and Space Administration
NCEP	U.S. National Centers for Environmental Prediction
NEOS	U.S. National Earth Orientation Service
NERC	Natural Environment Research Council
NGS	U.S. National Geodetic Survey
NIPR	National Institute for Polar Research
NNR	No-net-rotation
NOAA	National Oceanic and Atmospheric Administration
NRAO	U.S. National Radio Astronomy Observatory
NRCan	Natural Resources, Canada (formerly: EMR)
NUVEL	Northwestern University Velocity Model
OSO	Onsala Space Observatory
QC	quality control
PC	Product Centre
PP	Pilot Project
ppb	parts per billion (10^{-9})
RFI	radio frequency interference
rms, RMS	Root Mean Square
ROB	Royal Observatory of Belgium
SB	Special Bureau
SHA	Shanghai Observatory
SIMB	Service d'Installation et de Maintenance des Balises DORIS
SINEX	Solution (Software/technique) INdependent EXchange Format
SIO	Scripps Institution of Oceanography
SLR	Satellite Laser Ranging
SOD	CNES Service d'Orbitographie DORIS
SPBU	St Petersburg University
SSALTO	Segment Sol multi-mission d'ALTimétrie, d'Orbitographie et de localisation précise
TAI	Temps Atomique International (International Atomic Time)
TC	Technique Centre
TIGA	GPS Tide Gauge Benchmark Monitoring
TIGO	Transportable Integrated Geophysical Observatory

TRF	Terrestrial Reference Frame
TU	Technical University
USNO	United States Naval Observatory
UT	University of Texas
UT, UT1	Universal Time
UTC	Coordinated Universal Time
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry
VSI	VLBI Standard Interface
WRMS	Weighted Root Mean Square
ZPD	zenith path delay